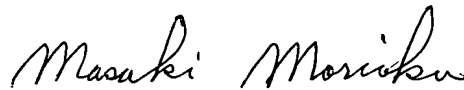


CERTIFICATION OF TRANSLATION

I, Masaki Morioka, residing at Iwai Bldg., 4th Floor, 16-5 Shimizu 1-Chome, Suginami-Ku, Tokyo, 167-0033, Japan, and being fully conversant in both the Japanese Language and the English Language hereby certify that the annexed is a true translation into the English Language of Japanese Patent Application No. 2003-094169 filed in the Japanese Patent Office on March 31, 2003.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

A handwritten signature in cursive script, reading "Masaki Morioka", positioned above a horizontal line.

Masaki Morioka

Dated this 1st day of March, 2007

(TRANSLATION)

PATENT OFFICE
JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this Office.

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[Title of the Invention] LIQUID CRYSTAL DISPLAY AND METHOD OF
MANUFACTURING THE SAME

[Number of Claims] 20

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[Title of the Invention] LIQUID CRYSTAL DISPLAY AND METHOD OF
MANUFACTURING THE SAME

[Claims]

[Claim 1]

A liquid crystal display comprising:

a liquid crystal material sandwiched between substrates,
wherein the liquid crystal material includes a monomer material
having a structure expressed by chemical formula 1:

[Chemical formula 1]

$X-R$

(where X represents an acrylate group or a methacrylate group and
R represents an organic group having a steroid skeleton); and

an ultraviolet-cured substance comprising a system
including the monomer material, formed at an interface of the
substrates.

[Claim 2]

A liquid crystal display comprising:

a liquid crystal material sandwiched between substrates,
wherein the liquid crystal material includes a monomer material
having a structure expressed by chemical formula 2:

[Chemical formula 2]

X_1-R-X_2

(where X_1 and X_2 represent an acrylate group or a methacrylate group
and R represents a divalent organic group having a steroid
skeleton); and

an ultraviolet-cured substance comprising a system
including the monomer material, formed at an interface of the

substrates.

[Claim 3]

A liquid crystal display comprising:

a liquid crystal material sandwiched between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 3:

[Chemical formula 3]

$X-R$

(where X represents an acrylate group or a methacrylate group and R represents an organic group having a steroid skeleton) and a monomer material having a structure expressed by chemical formula 4:

[Chemical formula 4]

$X_1-R_1-X_2$

(where X_1 and X_2 represent an acrylate group or a methacrylate group and R_1 represents a divalent organic group having a steroid skeleton); and

an ultraviolet-cured substance comprising a system including the monomer materials, formed at an interface of the substrates.

[Claim 4]

A method of manufacturing a liquid crystal display comprising the steps of:

sandwiching a liquid crystal material between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 5:

[Chemical formula 5]

$X-R$

(where X represents an acrylate group or a methacrylate group and R represents an organic group having a steroid skeleton); and

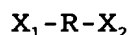
irradiating the liquid crystal material with ultraviolet rays to cure the monomer material, thereby forming an ultraviolet-cured substance at an interface of the substrate.

[Claim 5]

A method of manufacturing a liquid crystal display comprising the steps of:

sandwiching a liquid crystal material between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 6:

[Chemical formula 6]



(where X_1 and X_2 represent an acrylate group or a methacrylate group and R represents a divalent organic group having a steroid skeleton) and

irradiating the liquid crystal material with ultraviolet rays to cure the monomer material, thereby forming an ultraviolet-cured substance at an interface of the substrate.

[Claim 6]

A method of manufacturing a liquid crystal display comprising the steps of:

sandwiching a liquid crystal material between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 7:

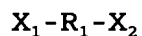
[Chemical formula 7]



(where X represents an acrylate group or a methacrylate group and

R represents an organic group having a steroid skeleton) and a monomer material having a structure expressed by chemical formula 8:

[Chemical formula 8]



(where X_1 and X_2 represent an acrylate group or a methacrylate group and R_1 represents a divalent organic group having a steroid skeleton); and

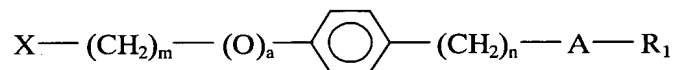
irradiating the liquid crystal material with ultraviolet rays to cure the monomer materials, thereby forming an ultraviolet-cured substance at an interface of the substrate.

[Claim 7]

A liquid crystal display comprising:

a liquid crystal material sandwiched between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 9:

[Chemical formula 9]



(where X represents an acrylate group or methacrylate group; A represents a benzene ring or cyclohexane ring; R represents an alkyl group or alkoxy group having carbon atoms in a quantity in the range from 1 to 20; a represents 0 or 1; m represents an integral number in the range from 0 to 10; and n represents an integral number in the range from 0 to 2); and

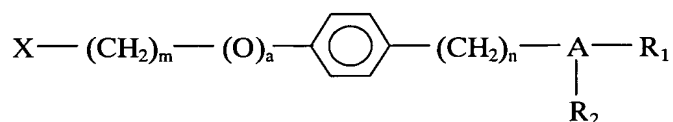
an ultraviolet-cured substance comprising a system including the monomer material, formed at an interface of the substrates.

[Claim 8]

A liquid crystal display comprising:

a liquid crystal material sandwiched between substrates,
wherein the liquid crystal material includes a monomer material
having a structure expressed by chemical formula 10:

[Chemical formula 10]



(where X represents an acrylate group or methacrylate group; A represents a benzene ring or cyclohexane ring; R₁ represents an alkyl group or alkoxy group having carbon atoms in a quantity in the range from 1 to 20; R₂ represents CH₃ or a fluorine atom; a represents 0 or 1; m represents an integral number in the range from 0 to 10; and n represents an integral number in the range from 0 to 2); and

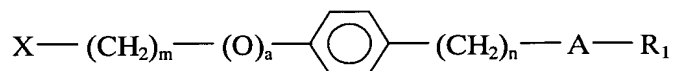
an ultraviolet-cured substance comprising a system including the monomer material, formed at an interface of the substrates.

[Claim 9]

A method of manufacturing a liquid crystal display comprising the steps of:

sandwiching a liquid crystal material between substrates,
wherein the liquid crystal material includes a monomer material
having a structure expressed by chemical formula 11:

[Chemical formula 11]



(where X represents an acrylate group or methacrylate group; A represents a benzene ring or cyclohexane ring; R represents an alkyl group or alkoxy group having carbon atoms in a quantity in the range from 1 to 20; a represents 0 or 1; m represents an integral number in the range from 0 to 10; and n represents an integral number in the range from 0 to 2); and

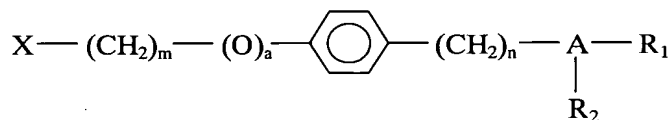
irradiating the liquid crystal material with ultraviolet rays to cure the monomer materials, thereby forming an ultraviolet-cured substance at an interface of the substrate.

[Claim 10]

A method of manufacturing a liquid crystal display comprising the steps of:

sandwiching a liquid crystal material between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 12:

[Chemical formula 12]



(where X represents an acrylate group or methacrylate group; A represents a benzene ring or cyclohexane ring; R₁ represents an alkyl group or alkoxy group having carbon atoms in a quantity in the range from 1 to 20; R₂ represents CH₃ or a fluorine atom; a represents 0 or 1; m represents an integral number in the range from 0 to 10; and n represents an integral number in the range from 0 to 2); and

irradiating the liquid crystal material with ultraviolet rays after being sandwiched between the substrates to cure the monomer materials, thereby forming an ultraviolet-cured substance at an interface of the substrate.

[Claim 11]

A method of manufacturing a liquid crystal display, comprising the steps of:

sandwiching a liquid crystal material including a polymeric material between substrates; and

irradiating the gap between the substrates with diffuse light to form an alignment control film.

[Claim 12]

A method of manufacturing a liquid crystal display, comprising the steps of:

sandwiching a liquid crystal material including a polymeric material between substrates; and

performing scan-irradiation of the gap between the substrates to form an alignment control film.

[Claim 13]

A method of manufacturing a liquid crystal display, comprising the steps of:

sandwiching a liquid crystal material including a polymeric material between substrates; and

performing scan-irradiation of the gap between the substrates with diffuse light to form an alignment control film.

[Claim 14]

A liquid crystal display comprising:

a liquid crystal material sealed between a pair of

substrates;

wherein the liquid crystal material comprises a fluorine type liquid crystal having negative dielectric constant anisotropy and an alignment assisting material for vertically aligning liquid crystal molecules;

the alignment assisting material comprises a monofunctional monomer and a multifunctional monomer of acrylic acid type or methacrylic acid type in a mixing ratio by weight in the range from 15:1 to 5:1, and a polymerization initiator which is in a mixing ratio of 2 % or less by weight to the total amount of the monofunctional monomer and the multifunctional monomer; and

the mixing ratio by weight between the liquid crystal material and the alignment assisting material is in the range from 99:1 to 90:10.

[Claim 15]

A liquid crystal display according to claim 14, wherein the purity of the monofunctional monomer and the multifunctional monomer is 98.5 % or more.

[Claim 16]

A liquid crystal display according to claim 14 or 15, wherein an unreacted residue of the monofunctional monomer exists in the mixed liquid crystal, and an unreacted residue of the multifunctional monomer and the polymerization initiator is 10 % or less.

[Claim 17]

A method of manufacturing a liquid crystal display comprising the steps of:

sealing a liquid crystal material between a pair of

substrates;

wherein the liquid crystal material comprises a fluorine type liquid crystal having negative dielectric constant anisotropy and an alignment assisting material for vertically aligning liquid crystal molecules;

the alignment assisting material comprises a monofunctional monomer and a multifunctional monomer of acrylic acid type or methacrylic acid type in a mixing ratio by weight in the range from 15:1 to 5:1, and a polymerization initiator which is in a mixing ratio of 2 % or less by weight to the total amount of the monofunctional monomer and the multifunctional monomer;

the mixing ratio by weight between the liquid crystal material and the alignment assisting material is in the range from 99:1 to 90:10; and

curing the alignment assisting material at an interface of the substrates to align the liquid crystal molecules vertically.

[Claim 18]

A method of manufacturing a liquid crystal display according to any of claims 14 to 17, wherein the mixed liquid crystal is injected using a dispenser injection method.

[Claim 19]

A method of manufacturing a liquid crystal display according to claim 18, wherein the mixed liquid crystal dispensed using the dispenser injection method comprises different materials which are used depending on dispensing positions on the substrates.

[Claim 20]

A liquid crystal display comprising:

a chiral nematic liquid crystal having negative dielectric

constant anisotropy sealed between a pair of substrates; and
an alignment control section formed by irradiating a monomer,
oligomer or polymer having at least one kind of functional group
mixed in a liquid crystal layer with an electromagnetic wave and
causing a reaction of the same such that the longitudinal direction
of liquid crystal molecules becomes substantially perpendicular
to either of the substrates when no voltage is applied.

[Detailed Description of the Invention]

[0001]

[Technical field to which invention belongs]

The present invention relates to a liquid crystal display and a method of manufacturing the same and, more particularly, to a liquid crystal display utilizing a condition in which liquid crystal molecules are vertically aligned when no voltage is applied and a method of manufacturing the same.

[0002]

[Prior Art]

Active matrix type liquid crystal displays (LCDs) that have been widely used include TN mode liquid crystal displays in which a liquid crystal material having positive dielectric constant anisotropy is aligned such that it is in parallel with surfaces of substrates and such that it is twisted at 90 deg. between the substrates which are opposed to each other. However, the TN mode has a problem in that it provides low viewing angle characteristics, and various studies are in progress in order to improve viewing angle characteristics.

[0003]

As an alternative to this method, MVA (Multi-domain Vertical Alignment) method has been developed in which a liquid crystal material having negative dielectric constant anisotropy is vertically aligned and in which tilting directions of liquid crystal molecules are regulated by protrusions and slits provided on surfaces of substrates when a voltage is applied, and the method has successfully improved viewing angle characteristics.

[0004]

An MVA type liquid crystal display will be described with reference to Figs. 1 and 2. Fig. 1 is a perspective view showing the concept of the MVA type liquid crystal display. Fig. 2 is a conceptual diagram showing aligning directions of liquid crystal molecules on a pixel 7 of the MVA type liquid crystal display as viewed in a direction normal to a surface of a substrate thereof.

[0005]

In the MVA type liquid crystal display, as shown in Fig. 1, a liquid crystal material (liquid crystal molecules) 5 having negative dielectric constant anisotropy is vertically aligned between two glass substrates 21 and 22. A pixel electrode connected to a TFT which is not shown is formed on the glass substrate 21, and an opposite electrode is formed on the other glass substrate 22. Protrusions 61 and 62 are alternately formed on the pixel electrode and the opposite electrode, respectively. Vertical alignment films which are not shown are formed on the pixel electrode and the opposite electrode which are not shown and on the protrusions 61 and 62.

[0006]

When no voltage is applied to the liquid crystal molecules 5 with the TFT in an off-state, as shown in Fig. 1(a), the liquid crystal molecules 5 are aligned in a direction perpendicular to substrate interfaces. When the TFT is turned on, an electric field acts on the liquid crystal molecules 5, and tilting directions of the liquid crystal molecules 5 are regulated by the structure in which the protrusions 61 and 62 are formed. As a result, the liquid crystal molecules 5 are aligned in a plurality of directions in one pixel as shown in Fig. 1(b). For example, when the

protrusions 61 and 62 are formed as shown in Fig. 2, the liquid crystal molecules 5 are aligned in each of directions A, B, C and D. Since the liquid crystal molecules 5 are aligned in a plurality of directions when the TFTs are turned on in the MVA type liquid crystal display, preferable viewing angle characteristics can be achieved.

[0007]

In the above-described MVA method, vertical alignment films do not regulate the tilting directions of the liquid crystal molecules 5. Therefore, there is no need for an alignment processing step such as rubbing that is essential for horizontal aligning methods represented by the TN method. This is advantageous from the viewpoint of processing in that the problem of static electricity and waste which occurs during a rubbing process is eliminated and in that no washing process is required after an aligning process. Further, since problems such as display irregularities attributable to variation of a pre-tilt will not occur, there is another advantage in that a cost reduction can be achieved through simplification of processes and improvement of yield.

[0008]

Patent Document 1: JP-A-11-95221

Patent Document 2: JP-A-5-232465

Patent Document 3: JP-A-8-338993

Patent Document 4: JP-A-8-036186

[0009]

[Problems to be Solved by the Invention]

Although the MVA method has various advantages as thus

described, the simplification of processes, the improvement of yield and the cost reduction can be further encouraged if the existing step for forming vertical alignment films can be omitted. Further, although there is a need for forming vertical alignment films on mother glasses which are increasing in size as a result of the recent trend toward greater LCDs, a problem has arisen in that the existing alignment film printing apparatus may become unable to satisfy such a need.

[0010]

In the existing methods for forming vertical alignment films, there is a phenomenon in which horizontally aligned domains called white lines can remain in a vertically aligned region. There is a need for reducing or eliminating such white lines to suppress reduction in contrast.

[0011]

It is an object of the invention to provide a liquid crystal display and a method of manufacturing the same in which the existing step for forming vertical alignment films can be omitted to achieve a cost reduction.

[0012]

It is another object of the invention to provide a liquid crystal display and a method of manufacturing the same in which vertical alignment films can be easily formed even if the mother glasses are large-sized.

[0013]

It is still another object of the invention to provide a liquid crystal display and a method of manufacturing the same in which white lines can be reduced to suppress reduction in contrast.

[0014]

[Means for Solving the Problem]

The above-described objects are achieved by a liquid crystal display having a liquid crystal material sandwiched between substrates, characterized in that:

the liquid crystal material includes a monomer material having a structure expressed by chemical formula 13:

[Chemical formula 13]

X-R

(where X represents an acrylate group or a methacrylate group and R represents an organic group having a steroid skeleton); and

an ultraviolet-cured substance comprising a system including the monomer material is formed at an interface of the substrates.

[0015]

[Modes of Carrying out the Invention]

[First Mode for Carrying Out the Invention]

A liquid crystal display and a method of manufacturing the same in a first mode for carrying out the invention will now be described with reference to Figs. 3 to 9. In the present mode for carrying out the invention, two substrates having no vertical alignment film formed thereon are provided opposite to each other to sandwich a liquid crystal material between them. The liquid crystal material includes a monomer material having a molecular structure in which director directions of liquid crystal molecules can be regulated and having a photoreactive group on one side of its skeleton. After the liquid crystal material is sandwiched between the substrates, an ultraviolet-cured substance (polymer)

obtained by curing the monomer material through irradiation with ultraviolet rays is formed on interfaces of the substrates. A common molecular structure in which director directions of liquid crystal molecules can be regulated is an alkyl chain. A photoreactive group is a skeleton which has an unsaturated double bond such as an acrylate group, a methacrylate group, a vinyl group or an allyl group and which can be polymerized with another molecule when irradiated with ultraviolet rays.

[0016]

Fig. 3 shows a basic principle 1 of the present mode for carrying out the invention. Immediately after the liquid crystal is injected, as shown in Fig. 3(a), liquid crystal molecules 5 which are mixed with a monofunctional monomer 2 having a hydrophobic skeleton 2a such as an alkyl chain and a photoreactive group 2b on one side of the skeleton are horizontally aligned. Nothing is formed on the surface of a substrate 22. When irradiated with ultraviolet rays, as shown in Fig. 3(b), a polymer film 4 is formed on the surface of the substrate 22 such that groups which regulate director directions of the liquid crystal molecules 5 align the liquid crystal molecules 5 perpendicularly to an interface. Unlike existing liquid crystals referred to as polymer-dispersed liquid crystals (PDLs), alignment is controlled using a polymer (resin) film 4 in the form of a thin film which is formed on the surface of the substrate 22 like an alignment film instead of forming a polymer throughout the liquid crystal layer. When polymers are constituted by only monofunctional monomers 2, the polymers are in a structure in which they are serially arranged as shown in Fig. 3(b), and the polymer film 4 becomes a resin film in which

the polymers are physically deposited on and caught in each other.
[0017]

Fig. 4 shows a basic principle 2 of the present mode for carrying out the invention. When bifunctional monomers 3 each having a hydrophobic skeleton 3a such as an alkyl chain and photoreactive groups 3b on both sides of the skeleton as shown in Fig. 4(a) or multifunctional monomers having a greater number of photoreactive groups (functional groups) are used in addition to monofunctional monomers 2, a polymer film 4 in the form of network that is chemically steric is formed, as shown in Fig. 4(b). A more rigid and reliable polymer film 4 can be obtained in this case.

[0018]

When monofunctional alkyl monomers in which only one photoreactive group is added to an ordinary alkyl chain C_nH_{2n+1} are used to erect liquid crystal molecules vertically, the vertically aligning property is not so high, and a problem remains in that it is difficult to reduce the mixing ratio of bifunctional monomers. Substantially no difference is observed in alignment even when alkyl chains are varied from C_{12} (lauryl) through C_{18} (stearyl). This is considered attributable to the fact that a simple alkyl chain as described above has high flexibility and that contribution to vertically aligning property becomes smaller as the alkyl chain becomes longer.

[0019]

Close studies and trials have revealed that the use of a material having a steroid skeleton as a component of the ultraviolet-cured resin to be formed makes it possible to improve

vertical alignment regulating capability. In particular, organic groups as shown in Figs. 5(a) to 5(d) are preferable among groups having a steroid skeleton. By using such a material having a steroid skeleton, vertically aligning properties higher than that achievable with simple alkyl monomers can be achieved even when the dose of the material is substantially halved in terms of molar ratio.

[0020]

In order to maintain the reliability of the liquid crystal display, it is essential to prevent the release of impurity ions into the liquid crystal. For this purpose, the ultraviolet-cured resin is formed using a system which has at least one ring structure and which is mixed with a bifunctional material having an acrylate group or a methacrylate group on one end thereof or a material having more functions. Close studies and trials have revealed that the use of such a material makes it possible to form a resin film having less monomer residues without adding a polymerization initiator. In particular, it is preferable to use materials as shown in Figs. 6(a) to 6(d) in which no spacer intervenes between a ring structure and an acrylate group or methacrylate group. In case that a spacer(s) intervenes, it is preferable that there is only one spacer $-\text{CH}_2-$.

[0021]

The ratio of unreacted residues of a multifunctional monomer having two or more functions as described above decreases as the mixing ratio of the monomer is increased, and electrical characteristics such as a voltage holding ratio are improved accordingly. However, it becomes unable to achieve vertical

alignment when the ratio is increased beyond a certain level. In order to solve this problem, bifunctional monomers having a steroid skeleton as shown in Fig. 5 are used. By substituting bifunctional monomers having a steroid skeleton as described above for all or part of the bifunctional monomers, it becomes possible to provide a resin film whose electrical characteristics and vertically aligning properties are balanced at a high level and to provide an excellent liquid crystal display.

[0022]

A detailed description will follow with reference to specific embodiments and comparative examples.

[Embodiment 1-1]

Monomers were fabricated which had a steroid skeleton as shown in Fig. 5 and in which an acrylate group was substituted for an OH group in the figure. The monomers in an amount of 1.3×10^{-4} mol/g were dissolved in a negative liquid crystal A manufactured by Merck Ltd.. Bifunctional monomers having a ring structure as shown in Fig. 6 in an amount of 1.3×10^{-5} mol/g that is one-tenth of the above amount were then dissolved in the liquid crystal material. The resultant mixed liquid crystals were injected and sealed in evaluation cells. Two glass substrates having ITO (indium tin oxide) films formed thereon as electrodes were used as an evaluation cell, and the substrates were combined with a cell thickness of 4.25 μm . The substrates used were formed with no alignment film and were irradiated with ultraviolet rays of 1500 mJ on surfaces thereof.

[0023]

An observation of the state of alignment of the evaluation

cells immediately after fabrication revealed that there was fluid alignment and that both of horizontal alignment and vertical alignment existed. Thereafter, the evaluation cells were annealed for 30 minutes at 90°C and were irradiated with unpolarized ultraviolet rays of 9000 mJ after being cooled. An observation of alignment revealed that perfect vertical alignment was achieved throughout the evaluation cells.

[0024]

[Comparative Example 1-1]

An experiment similar to Embodiment 1-1 was conducted using a monomer material having no steroid skeleton, i.e. lauryl acrylate $\text{CH}_2=\text{CHCOOC}_{12}\text{H}_{25}$.

[0025]

As a result, substantially no change in alignment was observed between states before and after irradiation with ultraviolet rays, and preferable vertical alignment could not be achieved. When the dose of the material was gradually increased, vertical alignment on the same level was achieved at a dose of 2.4 to 2.5×10^{-4} mol/g which was about twice that in the embodiment (the bifunctional monomers were dissolved in the fixed ratio of one-tenth, i.e., in an amount of 2.4×10^{-5} mol/g). A similar experiment conducted using stearyl acrylate $\text{CH}_2=\text{CHCOOC}_{18}\text{H}_{37}$ indicated no clear difference from lauryl acrylate.

[0026]

[Comparative Example 1-2]

An experiment similar to Comparative Example 1-1 was conducted by using a monomer HDDA having no ring structure instead of bifunctional monomers having a ring structure as shown in Fig.

6, dissolving it in the same amount 1.3×10^{-5} mol/g in the liquid crystal material, and fabricating an evaluation cell from the resultant mixed liquid crystal.

[0027]

As a result, substantially no change in alignment was observed between states before and after irradiation with ultraviolet rays similarly to the Comparative Example 1-1, and vertical alignment was not achieved when irradiation was continued with ultraviolet rays of 9000 mJ unlike Embodiment 1-1. Then, Irg651 of 0.2 % by weight as a polymerization initiator was added to the liquid crystal which was then irradiated with ultraviolet rays, and the liquid crystal as a whole could be vertically aligned. However, measurement of the voltage holding ratio revealed that there was a significant reduction in the voltage holding ratio around the injection hole.

[0028]

[Comparative Example 1-3]

An experiment similar to Comparative Example 1-1 was conducted by using bifunctional monomers having one or more ring structures as shown in Fig. 6 and providing CH_2 between a ring structure and an acrylate group or a methacrylate group (the relationship of Fig. 6(d) to Fig. 6(c)), and differences in reactivity were observed. CH_2 was provided in different quantities, i.e., 1, 2, 4 and 6 with the mixing ratio and the quantity of the monomers added in terms of mol kept unchanged.

[0029]

As a result, changes before and after irradiation with ultraviolet rays abruptly diminished when two CH_2 were provided

substantially regardless of the number of ring structures and the structure for connecting rings, and vertical alignment was not achieved in samples having four and six CH₂ after irradiation with ultraviolet rays however great the dose was.

[0030]

[Embodiment 1-2]

Lauryl acrylate of 2.4×10^{-4} mol/g and bifunctional monomers having ring structures as shown in Fig. 6 were dissolved in a negative liquid crystal A manufactured by Merck Ltd., and resultant mixed liquid crystals were injected and sealed in evaluation cells. The evaluation cells were fabricated with the molar ratio of the bifunctional monomers to lauryl acrylate varied. Other conditions for fabrication followed those for Embodiment 1-1, and two glass substrates having ITO films formed thereon as electrodes were used for an evaluation cell and were combined with a cell thickness of 4.25 μ m. The substrates used had no alignment film formed thereon and were irradiated with ultraviolet rays of 1500 mJ/cm² on surfaces thereof.

[0031]

Fig. 7 shows results of evaluation of voltage holding ratios and vertically aligning properties after irradiation with ultraviolet rays of 9000 mJ/cm², the holding period being 1.67 s. The abscissa axis of Fig. 7 represents mixing ratios between C₁₂ and the bifunctional monomers, and the ordinate axis represents relative holding ratios. A holding ratio of 1.0 is the value of a holding ratio in a saturated state. Referring to the symbols above the horizontal arrows in the figure, the circle represents a region of mixing ratios in which vertical alignment could be

achieved; the triangle represents a region of mixing ratios in which horizontal alignment partially remained; and the cross represents a region of mixing ratios in which horizontal alignment remained as it was. As shown in Fig. 7, the voltage holding ratio gradually increased with the ratio of the bifunctional monomers, and saturation was substantially reached at a ratio in the range from about 7:1 to 6:1 for any of the materials. However, vertically aligning properties gradually deteriorated on the contrary, and some regions appeared with insufficient verticalness around when the mixing ratio dropped below 10:1. The results were conflicting in that vertical alignment cannot be achieved under conditions that allow the best holding ratio to be achieved.

[0032]

A similar experiment was conducted with the half of the dose of the bifunctional monomers replaced with bifunctional monomers having structures as shown in Figs 8(a) to 8(d) which had steroid skeletons and in which OH groups were acrylate groups. Fig. 9 shows the result. The abscissa axis of Fig. 9 represents mixing ratios between C_{12} and the bifunctional monomers, and the ordinate axis represents relative holding ratios. Referring to the symbols above the horizontal arrows in the figure, the circle represents a region of mixing ratios in which vertical alignment could be achieved; the triangle represents a region of mixing ratios in which horizontal alignment partially remained; and the cross represents a region of mixing ratios in which horizontal alignment remained as it was. As shown in Fig. 9, while no significant change was observed in the process of the change in the voltage holding ratio, vertical alignment could be achieved in an increased range

to allow both of the voltage holding ratio and vertical alignment to be achieved at a high level which had not been achievable so far.

[0033]

As described above, since the use of the present mode for carrying out the invention eliminates the need for an alignment film forming step for liquid crystal displays, in particular, vertical alignment type displays represented by MVA types, a significant cost reduction can be achieved.

[0034]

Further, a liquid crystal alignment control layer can be easily formed even on an ultra-large mother glass which cannot be sufficiently handled with alignment film printing apparatus according to existing methods without being affected by the size of the same. The invention also makes it possible to provide liquid crystal displays utilizing substrates which are difficult to print such as substrates having great irregularities and substrates having curved surfaces.

[0035]

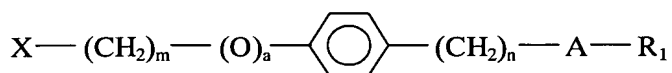
[Second Mode for Carrying Out the Invention]

A liquid crystal display and a method of manufacturing the same in a second mode for carrying out the invention will now be described with reference to Figs. 10 to 14. As described above, not so high vertical alignment is achieved by monofunctional alkyl monomers in which only one photoreactive group is added to an ordinary alkyl chain C_nH_{2n+1} in order to align the liquid crystal molecules vertical.

[0036]

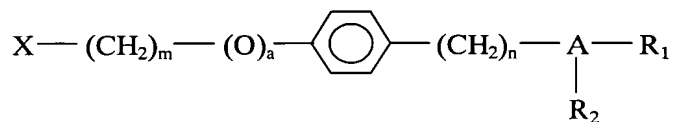
Close studies and trials revealed that vertical alignment regulating capability could be improved by using a material system in which a ring structure is introduced between ordinary alkyl chains as a component of the ultraviolet-cured resin to be formed. More specifically, the liquid crystal material includes a monomer material having a structure expressed by chemical formula 14:

[Chemical formula 14]



(where X represents an acrylate group or methacrylate group; A represents a benzene ring or cyclohexane ring; R represents an alkyl group or alkoxy group having carbon atoms in a quantity in the range from 1 to 20; a represents 0 or 1; m represents an integral number in the range from 0 to 10; and n represents an integral number in the range from 0 to 2) or a monomer material having a structure expressed by chemical formula 15:

[Chemical formula 15]



(where X represents an acrylate group or methacrylate group; A represents a benzene ring or cyclohexane ring; R_1 represents an alkyl group or alkoxy group having carbon atoms in a quantity the range from 1 to 20; R_2 represents CH_3 or a fluorine atom; a represents 0 or 1; m represents an integral number in the range

from 0 to 10; and n represents an integral number in the range from 0 to 2), and the liquid crystal material is sandwiched between substrates and is then irradiated with ultraviolet rays to cure the monomer material, thereby forming an ultraviolet-cured substance on an interface of a substrate.

[0037]

At this time, the value n is preferably 0 from the viewpoint of vertical aligning power, and a preferable result will then be obtained with regard to vertical aligning power relative to the dose in terms of molar ratio. However, solubility is slightly reduced. Further, the value a is preferably 0 to reduce the molecular weight, and the value m is set at 0 in this case to make it possible to provide a structure in which a reacting group is directly coupled with a benzene ring. Such values may be appropriately set with respect to the liquid crystal to be mixed to achieve higher effects.

[0038]

The most significant problem in utilizing the above-described monomer is solubility. A material is useless if it cannot be dissolved in a liquid crystal that is the base material to be used with the same in an amount required to achieve vertical alignment however high vertical aligning power it may have. Close studies and trials revealed that a resin film capable of achieving preferable vertical alignment cannot be formed unless the sum of the number of carbon atoms of the group represented by R_1 and the integral number n is 20 or less. It was also revealed that the advantage of the monomer over alkyl monomers in the related art is reduced when the sum of the number of carbon atoms of the group

represented by R_1 and the integral number n is less than 5. Thus, the sum of the number of carbon atoms of the group represented by R_1 and the integral number n must be in the range from 5 to 20 as a requirement for forming the monomer material. Especially, the group R_1 is desirably an alkyl group having about 6 to 12 carbons or an alkoxy group that is similar to the same in length.

[0039]

CH_3 or a fluorine atom may be introduced as R_2 in the formula to improve the vertical aligning power and solubility. Figs. 10(a) to 10(d) show examples of monofunctional monomer materials in the present mode for carrying out the invention. The use of such a material makes it possible to achieve vertically aligning properties higher than those achievable with a simple alkyl monomer even when the dose of the former is about one-half the dose of the latter in terms of molar ratio.

[0040]

In order to maintain the reliability of a liquid crystal display, it is essential to prevent the release of impurity ions into the liquid crystal. For this purpose, an ultraviolet-cured resin is formed using a system which has at least one ring structure and which is mixed with a bifunctional material having an acrylate group or a methacrylate group on one end thereof or a material having more functions. Close studies and trials have revealed that the use of such a material makes it possible to form a resin film having less monomer residues without adding a polymerization initiator. In particular, it is preferable to use materials as shown in Figs. 11(a) to 11(d) in which no spacer intervenes between a ring structure and an acrylate group or methacrylate group. In

case that a spacer(s) intervenes, it is preferable that there is only one spacer $\text{-CH}_2\text{-}$.

[0041]

The ratio of unreacted residues of monomers having two or more functions as described above decreases as the mixing ratio of the monomers is increased, and electrical characteristics such as a voltage holding ratio are improved accordingly. However, it becomes unable to achieve vertical alignment with an alkyl monomer according to the related art when the ratio is increased beyond a certain level. However, the use of a monofunctional monomer as shown in the present mode for carrying out the invention solves the problem and makes it possible to provide a resin film whose electrical characteristics and vertically aligning properties are balanced at a high level and to provide an excellent liquid crystal display.

[0042]

A detailed description will follow with reference to specific embodiments and comparative examples.

[Embodiment 2-1]

Monomers were fabricated which had structures including a ring structure between alkyl chains as shown in Fig. 10. The monomers in an amount of 1.3×10^{-4} mol/g were dissolved in a negative liquid crystal A manufactured by Merck Ltd. Bifunctional monomers having a ring structure as shown in Fig. 11 in an amount of 1.3×10^{-5} mol/g that is one-tenth of the above amount were then dissolved in the liquid crystal A. The resultant mixed liquid crystals were injected and sealed in evaluation cells. Two glass substrates having ITO films formed thereon as electrodes were used as an

evaluation cell, and the substrates were combined with a cell thickness of 4.25 μm . The substrates used were formed with no alignment film and were irradiated with ultraviolet rays of 1500 mJ/cm^2 on surfaces thereof.

[0043]

An observation of the state of alignment of the evaluation cells immediately after fabrication revealed that there was fluid alignment and that both of horizontal alignment and vertical alignment existed. Thereafter, the evaluation cells were annealed for 30 minutes at 90°C and were irradiated with unpolarized ultraviolet rays of 9000 mJ/cm^2 after being cooled. An observation of alignment revealed that perfect vertical alignment was achieved throughout the evaluation cells. Fig. 12 shows a phenomenon in which horizontally aligned domains appearing as white lines are formed in a vertically aligned region. Although defects in the form of white lines were observed in some parts in an initial state of vertical alignment as shown in Fig. 12(b), they completely disappeared when a pressure was applied to those locations and did not appear again thereafter.

[0044]

[Comparative Example 2-1]

An experiment similar to Embodiment 2-1 was conducted using an ordinary alkyl monomer material having no ring structure between alkyl chains, i.e. lauryl acrylate $\text{CH}_2=\text{CHCOOC}_{12}\text{H}_{25}$.

[0045]

As a result, substantially no change in alignment was observed between states before and after irradiation with ultraviolet rays, and preferable vertical alignment could not be

achieved. When the dose of the material was gradually increased, a vertically aligned state was achieved at a dose of 2.4 to 2.5×10^{-4} mol/g which was about twice that in the embodiment (the bifunctional monomers were dissolved at the fixed ratio of one-tenth, i.e., in an amount of 2.4×10^{-5} mol/g). However, many defects in the form of white lines were observed in the vertically aligned state as shown in Fig. 12(a). Thus, contrast was low, and roughness was noticeable in display of black and was not so much reduced even when a pressure was applied to locations with roughness. A similar experiment conducted using stearyl acrylate $\text{CH}_2=\text{CHCOOC}_{18}\text{H}_{37}$ indicated no clear difference from lauryl acrylate.

[0046]

[Comparative Example 2-2]

An experiment similar to Comparative Example 2-1 was conducted by using a monomer HDDA having no ring structure instead of bifunctional monomers having a ring structure as shown in Fig. 11, dissolving it in the same amount 1.3×10^{-5} mol/g in the liquid crystal material, and fabricating an evaluation cell from the resultant mixed liquid crystal.

[0047]

As a result, no significant change in alignment was observed between states before and after irradiation with ultraviolet rays just as in Comparative Example 2-1, and perfect vertical alignment was not achieved when irradiation was continued with ultraviolet rays of 9000 mJ unlike Embodiment 2-1. Then, Irg651 of 0.2 % by weight as a polymerization initiator was added to the liquid crystal which was then irradiated with ultraviolet rays, and the liquid crystal as a whole could be vertically aligned. However,

measurement of the voltage holding ratio revealed that there was a significant reduction in the voltage holding ratio around the injection hole.

[0048]

[Embodiment 2-2]

Solubility and vertically aligning properties were evaluated using materials having alkyl skeleton portions with different lengths. Fig. 13 shows examples of the materials used. First, when the material shown in Fig. 13(a) was used, the material dissolved in the liquid crystal in an amount of 1.5 % by weight but deposited during a process of vacuum injection when the amount was 1.8 % by weight. A cell was fabricated under the condition of 1.5 % by weight at which the material was soluble, and the state of alignment was observed after irradiating the same with ultraviolet rays, which revealed no significant change from the state before the irradiation. At this time, the sum of the number of carbon atoms of the group represented by R_1 and the integral number m in the above formula was 25.

[0049]

Solubility was then observed with the length of the alkyl skeleton portion gradually reduced. As a result, the material became soluble in an amount of 2.5 % or more by weight when the sum of the number of carbon atoms of the group R_1 and the integral number m became about 20. Since this means a reduction of about 20 % in terms of molecular weight, the soluble amount in terms of molar weight was increased by a factor of two or more.

[0050]

The material was dissolved in an amount of 1.3×10^{-4} mol/g

in a negative liquid crystal A manufactured by Merck Ltd. just as in Embodiment 2-1, and bifunctional monomers having ring structures as shown in Fig. 11 were then dissolved in an amount of 1.3×10^{-5} mol/g that is one-tenth of the above amount. Cells were fabricated using resultant mixed liquid crystals. An observation of alignment after irradiation with ultraviolet rays revealed that perfect vertical alignment was achieved throughout the evaluation cells.

[0051]

When the lengths of the alkyl skeleton portions of the monomers were reduced as shown in Figs. 13(b) and 13(c), vertical alignment was achieved but a phenomenon was observed, in which many white lines shown in Fig. 12(a) became visible to reduce the advantage of the materials over ordinary alkyl monomers. At that time, the sum of the number of carbon atoms of the group R_1 and the integral number m was about 3 or 4. When the lengths were further reduced, it became impossible to achieve perfect vertical alignment without relying upon other skeleton portions.

[0052]

[Embodiment 2-3]

Lauryl acrylate of 2.4×10^{-4} mol/g and bifunctional monomers having ring structures as shown in Fig. 11 were dissolved in a negative liquid crystal A manufactured by Merck Ltd., and resultant mixed liquid crystals were injected and sealed in evaluation cells. The evaluation cells were fabricated with the molar ratio of the bifunctional monomers to lauryl acrylate varied. Other conditions for fabrication followed those for Embodiment 2-1, and two glass substrates having ITO films formed thereon as electrodes were used

for an evaluation cell and were combined with a cell thickness of 4.25 μm . The substrates used had no alignment film formed thereon and were irradiated with ultraviolet rays of 1500 mJ/cm^2 on surfaces thereof.

[0053]

Results of evaluation of voltage holding ratios in a holding period of 1.67s and vertically aligning properties after irradiation with ultraviolet rays of 9000 mJ/cm^2 were the same as those in Fig. 7 in the first mode for carrying out the invention. A holding ratio of 1.0 is the value of a holding ratio in a saturated state. As illustrated, the voltage holding ratio gradually increased with the ratio of the bifunctional monomers, and saturation was substantially reached at a ratio in the range from about 7:1 to 6:1 for any of the materials. However, vertically aligning properties gradually deteriorated on the contrary, and some regions appeared with insufficient verticalness around when the mixing ratio dropped below 10:1. The results were conflicting in that vertical alignment cannot be achieved under conditions that allow the best holding ratio to be achieved.

[0054]

A similar experiment was conducted with the monomers replaced with monomers having structures as shown in Fig. 10 which had a ring structure between alkyl chains. Fig. 14 shows the result. The abscissa axis of Fig. 14 represents mixing ratios between the monomer materials in the present mode for carrying out the invention and the bifunctional monomers, and the ordinate axis represents relative holding ratios. Referring to the symbols above the horizontal arrows in the figure, the circle represents a region

of mixing ratios in which vertical alignment could be achieved; the triangle represents a region of mixing ratios in which horizontal alignment partially remained; and the cross represents a region of mixing ratios in which horizontal alignment remained as it was. As shown in Fig. 14, while no significant change was observed in the process of the change in the voltage holding ratio, vertical alignment could be achieved in an increased range to allow both of the voltage holding ratio and vertical alignment to be achieved at a high level which had not been achievable so far.

[0055]

As described above, since the use of the present mode for carrying out the invention eliminates the need for an alignment film forming step for liquid crystal displays, in particular, vertical alignment type displays represented by MVA types, a significant cost reduction can be achieved.

[0056]

Further, a liquid crystal alignment control layer can be easily formed even on an ultra-large mother glass which cannot be sufficiently handled with alignment film printing apparatus according to existing methods without being affected by the size of the same. The invention also makes it possible to provide liquid crystal displays utilizing substrates which are difficult to print such as substrates having great irregularities and substrates having curved surfaces.

[0057]

[Third Mode for Carrying Out the Invention]

A liquid crystal display and a method of manufacturing the same in a third mode for carrying out the invention will now be

described with reference to Figs. 15 and 16. In the present mode for carrying out the invention, a method will be described which is more effective than methods in the related art in reducing or completely suppressing white lines visually perceived in domains that remain in horizontal alignment instead of being vertically aligned (see Fig. 15). It has been difficult to suppress the generation of white lines at a process of forming a resin film on a liquid crystal panel sandwiching a liquid crystal layer including a polymeric material by irradiating the panel with light. The difficulty originates in the fact that when a system including a polymeric material is vertically aligned as a result of a reaction with the irradiating light, the tilt of liquid crystal molecules that stand up from a horizontal position greatly varies between adjoining regions to leave some horizontally aligned regions.

[0058]

Close studies and trials revealed that white lines can be reduced to a level lower than that achievable with methods in the related art or completely suppressed by making tilt differences small between regions that are uniformly reacting in the liquid crystal panel, i.e., regions that are being vertically aligned during the reaction of the system including the polymeric material to thereby eliminate regions left in horizontal alignment. The use of manufacturing a liquid crystal display in the present mode for carrying out the invention makes it possible to suppress reduction of contrast attributable to white lines and to thereby provide an excellent liquid crystal display.

[0059]

A detailed description will now be made with reference to

specific embodiments and comparative examples.

[Embodiment 3-1]

A monofunctional monomer having acrylate groups at alkyl chains having 11 to 18 CH_2 , a diacrylate type bifunctional monomer having a ring structure, and an initiator were dissolved in a negative liquid crystal A manufactured by Merck Ltd., and substrates which have no alignment film formed thereon and which has been subjected to an excimer UV process on surfaces thereof are combined with a cell thickness of $4.25\text{ }\mu\text{m}$ to fabricate a 15-inch type panel. An observation of the state of alignment of the liquid crystal panel immediately after the fabrication revealed that there was fluid alignment and that both of horizontal alignment and vertical alignment existed. Thereafter, the liquid crystal panel was annealed for 30 minutes at 90°C and was irradiated with unpolarized ultraviolet rays of 9000 mJ/cm^2 after being cooled. An observation of alignment revealed that vertical alignment had been achieved throughout the liquid crystal panel.

Fig. 15 shows states of generation of white lines on the panel thus fabricated depending on light sources. Figs. 15(a) and 15(b) show states of white lines generated as a result of irradiation with parallel light and diffuse light, respectively. As shown in Fig. 15(b), when irradiated with diffuse light, the liquid crystal panel could be fabricated with less white lines and display irregularities.

[0060]

[Embodiment 3-2]

In an experiment similar to Embodiment 3-1, scanning irradiation was carried out. Before scanning irradiation was used,

the luminance distribution of 15-inch type panel had a maximum variation of 30 % in irradiation intensity, and the variation was reduced to 10 % or less when scanning irradiation was used. Scanning irradiation thus suppressed the generation of white lines and allowed the liquid crystal panel to be fabricated with less display irregularities.

[0061]

[Embodiment 3-3]

An experiment similar to Embodiment 3-1 was conducted to examine a relationship between doses of irradiation and voltage holding ratios. Fig. 16 shows the relationship between doses of irradiation and holding ratios thus identified. The abscissa axis of Fig. 16 represents doses of irradiation, and the ordinate axis represents voltage holding ratios. As shown in Fig. 16, doses of irradiation in the range from 8000 mJ/cm² to 30000 mJ/cm² are suitable from the viewpoint of reliability, and irradiation in doses smaller or greater than the range results in low reliability. In particular, a desirable dose of irradiation is 9000 mJ/cm². Further, reduction of reliability in the neighborhood of the injection hole could be prevented by using a visible light sealer. Reduction of reliability attributable to breakage of liquid crystal molecules including the polymeric material could be prevented by irradiating them with a wavelength in the range from 200 nm to 330 nm with intensity that was 0 to 20 % or less of the intensity of wavelengths in the range from 200 nm to 800 nm. Further, reduction of reliability could be prevented by using multi-step irradiation in which a first cycle of irradiation was performed with light of low intensity and followed by second and later cycles

of irradiation with higher intensity.

[0062]

[Embodiment 3-4]

An experiment similar to Embodiment 3-1 was conducted using substrates which had been subjected to plasma processing on surfaces thereof. The substrates allowed a liquid crystal panel having less display irregularities to be fabricated when compared to substrates which had not been subjected to any surface modifying process. Similarly, absorption of monomers onto the surfaces of the substrates was prevented by applying a voltage or heat when the liquid crystal including the polymeric material was injected to reduce the density distribution of the monomers, which allowed a liquid crystal panel to be fabricated with less display irregularities.

[0063]

[Embodiment 3-5]

An experiment similar to Embodiment 3-1 was conducted using horizontally aligning spacers. The generation of white lines was not observed on a liquid crystal panel utilizing the horizontally aligning spacers. Further, the surface tension of the horizontally aligning spacers is desirably 40 dyn/cm or more. When a press process was performed in an experiment similar to Embodiment 3-1, white lines could be reduced.

[0064]

As described above, since the use of the present mode for carrying out the invention eliminates the need for an alignment film forming step for liquid crystal displays, in particular, vertical alignment type displays represented by MVA types, a

significant cost reduction can be achieved.

[0065]

Further, a liquid crystal alignment control layer can be easily formed even on an ultra-large mother glass which cannot be sufficiently handled with alignment film printing apparatus according to existing methods without being affected by the size of the same. The invention also makes it possible to provide liquid crystal displays utilizing substrates which are difficult to print such as substrates having great irregularities and substrates having curved surfaces.

[0066]

[Fourth Mode for Carrying Out the Invention]

A liquid crystal display and a method of manufacturing the same in a fourth mode for carrying out the invention will now be described with reference to Figs. 17 to 36. Fig. 17 schematically illustrates LCD manufacturing processes according to the related art. According to TN types and MVA types in the related art, an alignment film 30 is formed on a transparent substrate 21 made of glass or plastic as shown in Fig. 17(a) (Fig. 17(b)). As occasions demand, a rubbing process is performed in which the alignment film 30 is rubbed with a roller around which a cloth is wound as shown in Fig. 17(c). Then, another transparent substrate 22 which has been subjected to similar processes is provided opposite to the transparent substrate 21 (Fig. 17(d)), and the substrates are combined with a seal material 31 applied to the peripheries thereof. Next, a liquid crystal 5 is injected through a liquid crystal injection hole that is an opening in part of the seal material 31 (Fig. 17(e)). The liquid crystal injection

hole is then closed to complete the liquid crystal panel (Fig. 17(f)). A dispenser-injection method may be used for the injection of the liquid crystal instead of vacuum injection as described above.

[0067]

While the alignment film 30 is formed before the liquid crystal 5 is injected in the method shown in Fig. 17, a liquid crystal display panel has been invented in which a layer having an alignment controlling function is formed after the liquid crystal is injected as indicated in the above-described modes for carrying out the invention. Fig. 18 schematically shows a method for forming an alignment control layer after a liquid crystal is injected. First, two substrates 21 and 22 to which no alignment film 30 has been applied yet are combined so as to leave a predetermined cell gap between them (Fig. 18(a)). Next, as shown in Fig. 18(b), a liquid crystal 5' which is a mixture of a liquid crystal material 5 and alignment control materials such as ultraviolet-cured monomers or oligomers (hereinafter generally referred to as monomers) is injected to form an alignment control layer 30' in the layer including the liquid crystal as shown in Fig. 18(c), thereby vertically aligning the liquid crystal molecules 5. The step of forming the alignment control layer 30' will be described in more detail using Figs. 18(b-1) to 18(b-3). All of the figures show the neighborhood of the substrate 21. As shown in Fig. 18(b-1), UV light is directed to a surface of the substrate. Thus, as shown in Fig. 18(b-2), monomers M at the interface between the mixed liquid crystal 5' and the substrate 21 are polymerized into a polymer P1. As irradiation with UV light is continued further, a polymer

P2 aligned vertically to the polymer P1 at the interface with the substrate is formed as shown in Fig. 18(b-3), and the polymers P1 and P2 function as a vertical alignment control layer to align the liquid crystal molecules 5 vertically.

[0068]

The above-proposed technique primarily relates to the alignment of a liquid crystal, and no mention has been made on electrical characteristics of a liquid crystal cell. In general, an active matrix LCD having switching elements such as TFTs (thin film transistors) must have a high voltage holding ratio at the liquid crystal cell thereof in light of its principle. The proposed technique in the related art has a problem in that display irregularities occur because a high voltage holding ratio cannot be maintained.

[0069]

Fig. 19 shows display irregularities 16 which are observed when a liquid crystal display panel 10 of a 15-inch type active matrix LCD is turned on. For example, display in halftones may result in display irregularities 16 which are regions appearing darker than a central region of the screen, the irregularities spreading from liquid crystal injection holes 14 that are openings in a seal material 12. Fig. 20 is a graph showing a comparison between voltage-transmittance (gradation transmittance) characteristics of normal and abnormal parts in the case of storage driving. It will be understood that the voltage-transmittance characteristics of an abnormal part having a light display irregularity (the line connecting symbols ■) are shifted toward a high voltage side from those of a normal part (the line connecting

symbols ♦) and the characteristics of another abnormal part having a dark display irregularity (the line connecting symbols ▲) are further shifted toward the high voltage side. This indicates that the voltage holding ratio of the liquid crystal is low in positions where display irregularities occur. An irregular part has a lower voltage holding ratio, the darker the part is. The present mode for carrying out the invention is aimed at improving the voltage holding ratio of a liquid crystal while aligning liquid crystal molecules vertically.

[0070]

Fig. 21 shows the problem using large panels (equivalent to a 15-inch type) for evaluation of voltage holding ratios which are formed by combining a pair of substrates having transparent electrodes instead of a TFT substrate and a CF substrate. The figures show results of measurement of voltage holding ratios of liquid crystal cells in which a substrate A having a plurality of linear electrodes a-1 to a-n formed in an X-direction and a substrate B having a plurality of linear electrodes b-1 to b-n formed in a Y-direction are combined in a face-to-face relationship and in which the linear electrodes a and b are provided so as to form a matrix in combination with each other. Fig. 21(a) shows voltage holding ratios (VHR; %) measured on a liquid crystal layer after irradiating the same with UV having an irradiation energy of 300 mJ/cm^2 , the layer being made of a liquid crystal material in which a polymerization initiator G to be described later is mixed in a monomer material D in an amount of 50 % by weight (1 % by weight of the liquid crystal material as a whole). Fig. 21(b) shows voltage holding ratios (VHR; %) measured on a liquid crystal

layer after irradiating the same with UV having an irradiation energy of 300 mJ/cm^2 , the layer being made of a liquid crystal material in which the polymerization initiator G to be described later is mixed in the monomer material D in an amount of 2.5 % by weight (0.05 % by weight of the liquid crystal material as a whole). Both of the figures indicate that the voltage holding ratio is low in the vicinity of an injection hole (in the vicinity of a position where the electrode a-4 in the X-direction and the electrode b-1 in the Y-direction intersect with each other).

[0071]

Fig. 22 shows a relationship between a UV irradiation step for a liquid crystal cell in the present mode for carrying out the invention and voltage holding ratios. The abscissa axis of the figure represents irradiation energy (J), and the ordinate axis represents voltage holding ratios (%). The liquid crystal material used is a liquid that is a mixture of a liquid crystal A (98 % by weight), a monofunctional monomer D (1.825 % by weight) (91.7 % of which is unrefined), a bifunctional monomer B (0.125 % by weight) and an initiator G (0.05 % by weight). The intensity of the irradiating UV is 0.5 mW/cm^2 . As shown in Fig. 22, voltage holding ratios change depending on the irradiation energy of light (which is ultraviolet rays in this case) with which the liquid crystal cell is irradiated. The line connecting symbols o in the figure represents changes in a voltage holding ratio near an injection hole depending on changes in the irradiating energy, and the line connecting symbols ♦ in the figure represents changes in a voltage holding ratio in a central part of the cell depending on the irradiating energy.

[0072]

Fig. 22 also shows that the voltage holding ratios are low when the monomers which are alignment assisting materials present in the liquid crystal cell do not react or react insufficiently. The amount of residual monomers can be easily analyzed by disassembling the liquid crystal cell to collect the liquid crystal from substrate surfaces using an organic solvent and analyzing it using gas chromatography. As indicated by the three straight lines at the bottom of Fig. 22, the bifunctional monomer is consumed to leave no residue at a first phase of reaction and the polymerization initiator is consumed to leave no residue at a second phase of reaction. When the voltage holding ratio of the liquid crystal cell is reduced, the monofunctional monomer is left in a greater amount among the alignment assisting materials, and what is required is to cause a reaction of the monomer which has not reacted yet. Although the reaction of the monomer is promoted by increasing the irradiating energy, the survival rate will not become 0. Since deterioration of the liquid crystal material itself is caused by irradiation beside the problem of the reaction of the alignment assisting material, the irradiation must be performed within a required range.

[0073]

Fig. 23 is a graph for explaining how the specific resistance of the liquid crystal material is reduced by additives that are substances constituting the alignment assisting materials mixed in the liquid crystal. The abscissa axis represents materials in various conditions such as the liquid crystal A, monomers B, C, D and E, and polymerization initiators F and G. Specific

resistances (Ωcm) are shown along the ordinate axis in logarithmic representation. As shown in Fig. 23, the liquid crystal A has a specific resistance of $1.67 \times 10^{14} \Omega\text{cm}$ when it is not heated. The specific resistance of the liquid crystal A is decreased to $4.25 \times 10^{13} \Omega\text{cm}$ when subjected to a heating process for 20 minutes at 90°C . The specific resistance of the liquid crystal A after the addition of each material shown in Fig. 23 is a value obtained at a dose that is 1 % of the liquid crystal A and after performing a heating process for 20 minutes at 90°C .

[0074]

It is apparent from Fig. 23 that there is a small reduction of the specific resistance when the bifunctional monomers B ($M = 294$, solid, purity: 99.8 %) and C ($M = 366$ or more, solid) are added and that there is a great reduction when the monofunctional monomers D ($M = 240$, liquid, purity: 91.8 %) and E ($M = 324$, liquid, purity: 99.2%) are added. It is well known that it is required to inject a liquid crystal material having a high specific resistance in order to achieve a high voltage holding ratio. It is therefore required to eliminate unreacted monofunctional monomers in a mixed liquid crystal.

[0075]

The purity of a monomer has a significant influence on the voltage holding ratio. A monomer having a low purity includes a great amount of impurities, which can cause a great reduction of the voltage holding ratio. In the present embodiment, the purity of a monomer is represented in terms of GC (%) used in gas chromatography that is normally performed.

[0076]

There is a certain limit on the improvement of the voltage holding ratio when it is pursued only by increasing the dose of irradiation. An analysis on reaction processes revealed that a bifunctional monomer is first consumed to come short relative to a monofunctional monomer under conditions employed in the related art. It was found that it is very much effective to increase the amount of a bifunctional monomer and to irradiate it with light sufficiently in order to reduce the survival rate of a monofunctional monomer.

[0077]

Thus, it was found that a bifunctional monomer plays a very important roll in causing efficient reaction (consumption) of a monofunctional monomer. Figs. 24 to 29 show results of an examination on changes in the voltage holding ratio relative to doses of irradiation conducted by varying the amounts of bifunctional monomers. In each of the figures, the abscissa axis represents irradiation energy (J/cm^2), and the ordinate represents voltage holding ratios (%).

[0078]

Fig. 24 shows an effect that occurs at a liquid crystal injection hole of a liquid crystal cell as a result of an increase in the amount of the bifunctional monomer B shown in Fig. 23. The line connecting symbols \blacktriangle in the figure represents a result of an arrangement according to the related art using a liquid crystal material that is the liquid crystal A shown in Fig. 23 mixed with the monofunctional monomer D, the bifunctional monomer B in a normal amount, and the polymerization initiator G ($M = 256$, solid, purity: 99.8 %). The ion density is in the range from 300 to 500 pC/cm^2 .

The line connecting symbols o represents a result of an increase in the amount of the bifunctional monomer B. It is apparent that the voltage holding ratio was significantly improved to 96.8 %. The ion density is in the range from 50 to 90 pC/cm². Fig. 25 is similar to Fig. 24 except that it shows results obtained in a central part of the liquid crystal cell. The ion density is in the range from 120 to 180 pC/cm² in the result represented by the line connecting symbols ▲ in the figure. The line connecting symbols o represents an improvement of the voltage holding ratio to 98.1 %, the ion density being in the range from 30 to 60 pC/cm². Thus, a preferable voltage holding ratio is obtained by increasing the amount of the bifunctional monomer B also in the central part of the cell. The difference between voltage holding ratios at the liquid crystal injection hole and the central part can be reduced by increasing the amount of the bifunctional monomer B further.

[0079]

Fig. 26 is a graph showing a comparison between voltage holding ratios at the liquid crystal injection hole of the liquid crystal cell, the holding ratios being achieved by increasing the amount of the bifunctional monomer B shown in Fig. 23 and increasing the purity of the monofunctional monomer D, respectively. The line connecting symbols ♦ in the figure represents a result of the use of a liquid crystal material that is the liquid crystal A shown in Fig. 23 mixed with the monofunctional monomer D with an increased purity of 97.7 %, the bifunctional monomer B in a normal amount, and the polymerization initiator G. The line connecting symbols o represents a result of the use of a liquid crystal material that is mixed with the monofunctional monomer

D with purity of 91.8 %, the bifunctional monomer B in an increased amount, and the polymerization initiator G. It is apparent that a more significant improvement of the voltage holding ratio is achieved by increasing the amount of the bifunctional monomer than increasing the purity of the monofunctional monomer. Fig. 27 is similar to Fig. 26 except that it shows results obtained at the central part of the liquid crystal cell. A preferable voltage holding ratio is obtained by increasing the amount of the bifunctional monomer B also in the central part of the cell.

[0080]

Fig. 28 shows differences between voltage holding ratios that depend on the presence and absence of the polymerization initiator, the amount of the bifunctional monomer B being increased from that in Fig. 23. The line connecting symbols \times in the figure represents a result of the use of a liquid crystal material that is the liquid crystal A shown in Fig. 23 mixed with the monofunctional monomer D, the bifunctional monomer B with an increased amount, and no polymerization initiator. When no polymerization initiator is added, liquid crystal molecules are vertically aligned with an irradiation energy of 3 J or more. A voltage holding ratio of 97.5 % is achieved at an irradiation energy of 9 J. The ion density is in the range from 22 to 30 pC/cm². The line connecting o represents a result of the use of a liquid crystal material that is the liquid crystal A mixed with the monofunctional monomer D, the bifunctional monomer B in an increased amount, and the polymerization initiator G. The line is not significantly different from the line connecting symbols \times in the figure, which indicates that the presence or absence of the polymerization

initiator does not significantly contribute to voltage holding ratios. The ion density is in the range from 500 to 90 pC/cm² when there is the polymerization initiator. Fig. 29 shows a result obtained at the central part of the liquid crystal cell, the result being similar to that shown in Fig. 28. Liquid crystal molecules are vertically aligned at an irradiation energy of 3 J or more when there is no polymerization initiator. A voltage holding ratio of 98.7 % is achieved with an irradiation energy of 9 J. The ion density is in the range from 10 to 30 pC/cm². The ion density is in the range from 30 to 70 pC/cm² in the result represented by the line connecting symbols o.

[0081]

Any of Figs. 30 to 32 show a result of an examination on a relationship between the purity of the monofunctional monomers and voltage holding ratios at an injection hole of a liquid crystal cell. The monofunctional monomers used in the present mode for carrying out the invention was acrylic acid type liquids, and the height value of their purity was 99.4 %. It was revealed that a monomer allows a higher voltage holding ratio to be achieved the higher the purity of the monomer and that monomers having purity of 98.5 % or more are suitable for the purpose of eliminating irregularities at an injection hole. A mixed liquid crystal (alignment assisting material) preferably included 0 % polymerization initiator in order to achieve a high voltage holding ratio and a low ion density.

[0082]

A high voltage holding ratio was obtained when there was no unreacted residue of a bifunctional monomer and a polymerization

initiator in a panel after vertical alignment was achieved even though there was some unreacted residue of a monofunctional monomer in the mixed liquid crystal. At this time, it was required that the reaction proceed until the ratio of the unreacted part of the monofunctional monomer (the amount of the residue of the monofunctional monomer in the liquid crystal layer in the panel divided by the amount of the monofunctional monomer added in the mixed liquid crystal) increases from 5 % to 50 %.

[0083]

Fig. 30 shows a result of an examination on a relationship between irradiation energy and voltage holding ratios performed with the purity of the monofunctional monomer D shown in Fig. 23 varied. The line connecting symbols o in the figure represents a monofunctional monomer D having purity of 99.4 %. The line connecting symbols ▲ in the figure represents a monofunctional monomer D having purity of 98.8 %. The line connecting symbols ■ in the figure represents a monofunctional monomer D having purity of 97.7 %. The line connecting symbols ◇ in the figure represents a monofunctional monomer D having purity of 94.4 %. The line connecting symbols × in the figure represents a monofunctional monomer D having purity of 91.7 %. In any case, the bifunctional monomer B is added in an amount that is twice the amount proposed in the related art, and the polymerization initiator G is also added. The examples shown in Fig. 30 were in an atmosphere at 50°C for 1.67 seconds, and the irradiation energy density was 0.5 mW/cm². The monofunctional monomers D having impurity of 94.4 % or more resulted in voltage holding ratios in the range from 86 to 88 % and ion densities in the range from 228 to 224 pC/cm².

The monofunctional monomer D having impurity of 91.7 % resulted in a voltage holding ratio of 37 % and an ion density of 1370 pC/cm². It is apparent from Fig. 30 that a monofunctional monomer D provides a higher voltage holding ratio, the higher the purity of the monomer. [0084]

Fig. 31 shows a result of an examination on a relationship between irradiation energy and voltage holding ratios depending on differences in purity between the monofunctional monomers D, the examination having been conducted under the same conditions as Fig. 30 except that the amount of the bifunctional monomers was increased by a factor of 2.4. In the figure, the lines connecting symbols o, ▲, ■, ◇ and x, respectively, indicate monofunctional monomers D which were the same in purity as the respective ones in Fig. 30. In any of the samples, the bifunctional monomer B was added in an amount that was 2.4 times that in Fig. 30, and the polymerization initiator G was also added. At an irradiation energy of 6 J/cm², the monofunctional monomers D having impurity of 94.4 % or more resulted in voltage holding ratios in the range from 95 to 97 % and ion densities in the range from 61 to 84 pC/cm². The monofunctional monomer D having purity of 91.7 % resulted in a voltage holding ratio of 84 % and an improved ion density of 416 pC/cm². Fig. 31 also indicates that a monofunctional monomer D results in a higher voltage holding ratio, the higher the purity of the monomer. Fig. 31 also indicates that it is preferable to increase the amount of the bifunctional monomer B and to use a monofunctional monomer D having high purity especially in the region of an injection hole.

[0085]

Fig. 32 is a graph in which the purity (GC %) of monofunctional monomers D are plotted along the abscissa axis and voltage holding ratios (%) are plotted along the ordinate axis. The purity substantially linearly changed from 94.4 % up to 99.4 %, and changes in the voltage holding ratio were in the range from 97.2 % to 97.5 %.

[0086]

Fig. 33 shows a section of a liquid crystal panel which is suitable for use in the present mode for carrying out the invention. In the liquid crystal panel shown in Fig. 33, color filter layers 32 are formed on one substrate 21 in addition to active elements 33 such as TFTs and pixel electrodes 34. Such elements and electrodes are not formed on another substrate 22 in a face-to-face relationship, and only an opposite electrode 35 is formed on the same. No light shield layer is formed at least in a display area. When the substrates 21 and 22 are combined with a predetermined cell gap left therebetween to seal a liquid crystal 5 which is mixed with a monomer, since there is no light-blocking member such as bus lines and BM (black matrix) layer, the liquid crystal 5 mixed with a monomer can be efficiently irradiated with UV light from the side of the substrate 22.

[0087]

Fig. 34 shows a section of a liquid crystal panel which is also suitable for use in the present mode for carrying out the invention. In the liquid crystal panel shown in Fig. 34, color filters 32 are formed on one substrate 21 in addition to active elements 33 such as TFTs and pixel electrodes 34. Another substrate 22 facing the above substrate is formed of a plastic material or film material, and only an opposite electrode 35 is formed on the

substrate 22.

[0088]

When the substrates 21 and 22 are combined with a predetermined cell gap left therebetween to seal a liquid crystal 5 which is mixed with a monomer, since there is no light-blocking member such as bus lines, the liquid crystal 5 mixed with a monomer can be efficiently irradiated with UV light from the side of the substrate 22. At this time, in case that the mixed crystal 5 includes a polymerization initiator, it is advantageous to use a polymerization initiator which has high light-absorbing properties in the region of visible light. Since irradiation with ultraviolet rays is not preferable to prevent deterioration of the plastic or film substrate, the mixed crystal 5 is irradiated with visible light from the side of the substrate 22, and the mixed crystal 5 is thus efficiently irradiated with light.

[0089]

The liquid crystal panel in the present mode for carrying out the invention is suitable for fabrication using the so-called dispenser injection method in which a mixed liquid crystal is dispensed to at least one substrate and another substrate is thereafter combined with the same. Steps for manufacturing a liquid crystal display panel according to the dispenser injection method will be briefly described with reference to Fig. 35. First, as shown in Fig. 35(a), a liquid crystal 206 is dispensed from a liquid crystal dispenser which is not shown to a plurality of positions on a surface of an array substrate 21 having switching elements such as TFTs and color filters formed thereon. Next, an opposite substrate 22 is aligned with and bonded to the array

substrate 21, the opposite substrate having a common electrode formed in a display area thereof and having a UV seal material 202 applied around the display area which is cured when irradiated with ultraviolet rays (UV). This step is performed in vacuum. When the combined substrates are then returned into the atmosphere, the liquid crystal 206 between the combined array substrate 21 and the opposite substrate 22 is dispersed by the atmospheric pressure as shown in Fig. 35(b). Then, the seal material 202 is irradiated with UV light by a UV light source 208 that is moved in a moving direction 211 along the region where the seal material 202 is applied as shown in Fig. 35(c), whereby the seal material 202 is cured.

[0090]

The use of the dispenser injection method in panel manufacturing steps is strongly desired because it provides the possibility of a reduction in the panel manufacturing cost and an improvement in mass productivity for a first reason that it allows a significant reduction in the amount of the liquid crystal material used and a second reason that it allows a reduction in the liquid crystal injection time in comparison to the vacuum injection method which has been widely used for panel manufacture in the related art. The method is also advantageous in that it eliminates the need for liquid crystal injection holes 14 that are openings in a seal material 12 as shown in Fig. 19.

[0091]

The use of the dispenser injection method makes it possible to fabricate a liquid crystal panel by dispensing two or more kinds of mixed liquid crystals instead of one kind of mixed crystal.

For example, as shown in Fig. 36(a), a mixed liquid crystal dispensed may comprise a liquid crystal Lca which is a liquid crystal material including no alignment assisting material, a liquid crystal Lcb which is a mixture of a liquid crystal material and a monofunctional monomer, a liquid crystal Lcc which is a mixture of a liquid crystal material and a bifunctional monomer, a liquid crystal Lcd which is a mixture of a liquid crystal material, a monofunctional monomer, and a bifunctional monomer and a liquid crystal Lce which is a mixture of a liquid crystal material and a polymerization initiator. A liquid crystal panel having high reliability can be fabricated by at least two kinds or more among them.

[0092]

As shown in Fig. 36(b), a liquid crystal material Lc may be dispensed onto a substrate 21 by a dispenser (not shown) containing only the liquid crystal material Lc (first dispensing), and a monomer material α may then be dispensed onto the liquid crystal material Lc on the substrate 21 by a dispenser (not shown) containing only the monomer material α (second dispensing) to mix them.

[0093]

Alternatively, as shown in Fig. 36(c), the liquid crystal material Lc alone or a liquid that is a mixture of the liquid crystal material Lc and the monomer material α may be dispensed; different monomer materials β and γ may be dispensed on an opposite substrate; and the substrates 21 and 22 may be combined to produce various kinds of mixed crystals.

[0094]

A detailed description will now be made with reference to

embodiments and comparative examples.

[Embodiment 4-1]

Each of a pair of glass substrate having transparent electrodes (ITO films) patterned thereon was washed. Spacers of 4.0 μm (manufactured by Sekisui Chemical Co., Ltd.) were dispersed on one glass substrate, and a thermoset seal (manufactured by Mitsui Toatsu Chemicals Inc.) was applied to another glass substrate by a dispenser. Those substrates were combined to fabricate an open cell. A liquid crystal A (manufactured by Merck Ltd., $\Delta\epsilon = -3.8$) and a resin were mixed in a ratio of 98:2 by weight. The resin was obtained by mixing a monofunctional monomer D (manufactured by Wako Pure Chemical Industries, Ltd.) and a bifunctional monomer B (manufactured by Merck Ltd.) in a ratio of 15:1 by weight. A polymerization initiator G was mixed at 2.5 % by weight of the total weight of the monofunctional monomer and the bifunctional monomer.

[0095]

The mixed liquid crystal thus prepared was charged into the open cell using the vacuum injection method, and the injection hole was sealed with a visible light-cured resin. The liquid crystal cell was irradiated with ultraviolet rays (UV) having intensity of 0.5 mW/cm^2 . The relationship between survivability against irradiation energy and voltage holding ratios was as shown Fig. 22. The liquid crystal cell was processed at each required irradiation energy, and voltage holding ratios were measured. The liquid crystal cell was disassembled, and the survival rate of each material was obtained from the collected liquid crystal using a gas chromatographic analysis. While the survival rate of each

material became smaller the greater the irradiation energy, about 10 % of the monofunctional monomer survived even when irradiated with an energy of 15 J/cm². In the range in which the survival rate greatly decreased, the voltage holding ratio increased greatly. However, the increase in the holding ratio became small when the change in the survival rate became small.

[0096]

The voltage holding ratios were measured using an apparatus VHR-1 manufactured by TOYO Corporation, and the measurement was conducted at a measuring temperature of 50°C and a holding time of 1.67 s.

[0097]

[Embodiment 4-2]

Fig. 23 shows a result of an examination of the specific resistance of mixed crystals obtained by adding components of an alignment assisting material in a liquid crystal A. The liquid crystal A is the same as that used in Embodiment 4-1. When nothing was added, the liquid crystal had a specific resistance on the level of 10¹⁴ before being heated. When heated, the specific resistance decreased to the level of 10¹³. The reduction was on the same level as that of an ordinary mixed liquid crystal mixed with no alignment assisting material. The specific resistance of mixed liquid crystals AB and AC added with the bifunctional monomers B and C, respectively, decreased to the level of 10¹³, whereas the resistance of mixed liquid crystals AD and AE added with the monofunctional monomers D and E respectively decreased to the level of 10¹¹.

[0098]

[Embodiment 4-3]

An open cell similar to those in Embodiment 4-1 was fabricated. A mixed liquid crystal having a mixing ratio different from that of the mixed liquid crystal in Embodiment 4-1 was prepared. The mixed liquid crystal was obtained by mixing a liquid crystal A (manufactured by Merck Ltd., $\Delta\epsilon = -3.8$) with a resin in a ratio of 98:2 by weight. The resin was a mixture of a monofunctional monomer D (manufactured by Wako Pure Chemical Industries, Ltd.) and a bifunctional monomer B (manufactured by Merck Ltd.) in a ratio of 15:2.4 by weight. A polymerization initiator G was mixed at 2.5 % by weight of the total weight of the monofunctional monomer and the bifunctional monomer. The mixed liquid crystal thus prepared was charged and sealed in a way similar to that in Embodiment 4-1. The liquid crystal cell was irradiated with ultraviolet rays (UV) at an intensity of 0.5 mW/cm². Figs. 24 to 29 show results of a comparison between the relationship of voltage holding ratios to irradiation energy with the results of the Embodiment 4-1. The voltage holding ratio could be improved at both of a central part and an injection hole of the liquid crystal cell. While the voltage holding ratio of the mixed liquid crystal in Embodiment 4-1 was on the level of 70 %, the mixed liquid crystal of the present embodiment had an improved voltage holding ratio on the level of 97 %. There was a difference between their ion densities, i.e., the density range of 300 to 500 pC/cm² could be reduced to 50 to 90 pC/cm².

[0099]

[Embodiment 4-4]

An open cell similar to that in Embodiment 4-1 was fabricated.

A mixed liquid crystal different from that in Embodiment 4-3 was prepared. The mixed liquid crystal of the present embodiment had a composition similar to the mixed liquid crystal in Embodiment 4-3 except that the polymerization initiator G was excluded. Figs. 28 and 29 show results of an examination similar to that in Embodiment 4-3 carried out on the mixed liquid crystal excluding the polymerization initiator G thus prepared. The voltage holding ratio could be further improved from that in Embodiment 4-3 at both of the central part and injection hole of the liquid crystal cell. The voltage holding ratio could be improved to the level of 98 % at both of the central part and injection hole. The ion density could be halved from that in Embodiment 4-3.

[0100]

[Embodiment 4-5]

A mixed liquid crystal based on Embodiment 4-1 and a mixed liquid crystal based on Embodiment 4-3 were prepared. Both of the liquid crystals were obtained by mixing the liquid crystal A (manufactured by Merck Ltd., $\Delta\epsilon = -3.8$) with a resin in a ratio of 98:2 by weight. The weight ratios of the monofunctional monomer D and the bifunctional monomer B were the same as those in Embodiments 4-1 and 4-3, and the polymerization initiator G was also mixed in 2.5 % by weight of the total weight. An examination was carried out by varying the purity of the monofunctional monomer D. Specifically, a monofunctional monomer D1 having purity of 91.7 %, a monofunctional monomer D2 having purity of 94.4 %, a monofunctional monomer D3 having purity of 97.7 %, a monofunctional monomer D4 having purity of 98.8 % and a monofunctional monomer D5 having purity of 99.4 % were used. A comparison of voltage

holding ratios similar to that in Embodiment 4-3 revealed that a higher voltage holding ratio can be achieved, the higher the purity of a monomer, as shown in Figs. 30, 31 and 32.

[0101]

[Fifth Mode for Carrying Out the Invention]

A liquid crystal display and a method of manufacturing the same in a fifth mode for carrying out the invention will now be described. Among active matrix type liquid crystal displays, reflective liquid crystal displays which can be light-weight, thin and less power-consuming are recently attracting attention and are disclosed in the above-mentioned Patent Document 2 and Patent Document 3, for example. Any of such displays employs a method utilizing a TN liquid crystal in which the liquid crystal is twisted and aligned by performing a rubbing process on an alignment film. However, in the method disclosed in the Patent Document 2 for example, a problem arises in that alignment control through rubbing is difficult to perform because irregularities are formed on reflective pixel electrodes.

[0102]

It is an object of the present mode for carrying out the invention to solve the above-described problem, to simplify processing, to reduce the manufacturing cost, and to improve the yield of manufacture. A technique is used to control the alignment of a liquid crystal without using a rubbing process or any other aligning process (such as UV irradiation). Methods have been disclosed in Patent Document 4 and others in which processing is simplified by injecting a positive liquid crystal (a liquid crystal having a positive dielectric constant anisotropy) between

horizontal alignment films which have not been subjected to an aligning process. However, such methods necessitate a step of injecting a liquid crystal material between substrates at a temperature equal to or higher than a temperature at which transition of the liquid crystal into an isotropic phase takes place. The methods also necessitate some limitations on manufacturing steps, the limitations being different from those in injecting methods in the related art and including a need for rapid cooling at a rate of 10°C/sec or more at the time of phase transition from the isotropic phase to the liquid crystal phase. Further, since a liquid crystal has a small pre-tilt angle in horizontal alignment, the stability of alignment at irregular electrodes as disclosed in Patent Document 2 is lower than that achievable with the rubbing method.

[0103]

In the present mode for carrying out the invention, solid state properties of a vertical alignment film are controlled to provide a liquid crystal display which does not need an aligning process such as rubbing during injection at the room temperature similar to injection in the related art. The method will not cause any problem in aligning properties when used in a reflective liquid crystal display or transfective liquid crystal display having reflective electrodes in an unevenness configuration, to say nothing of a transmissive liquid crystal display.

[0104]

Referring to the technique specifically, in normal processing of a liquid crystal display utilizing the MVA method that is a VA type alignment control method originated with the

applicant, it is necessary to form vertical alignment films mainly composed of polyamic acid or polyimide on TFT and CF substrates using the printing method or spin coat method and to complete the alignment films through two baking steps, i.e., pre-baking and post-baking steps. The present mode for carrying out the invention is a method in which a monomer, an oligomer, and a polymer having one or more kinds of functional groups are mixed in a liquid crystal layer and are reacted (polymerized or cross-linked) with each other using UV light (electromagnetic wave) to achieve vertical alignment instead of forming alignment films on CF and TFT substrates. It is also a technique which makes it possible to improve the reliability, manufacturing cost, and manufacturing tact time of liquid crystal panels significantly.

[0105]

The present mode for carrying out the invention may be applied to transmissive, reflective or transreflective LCDs. Referring to the modes of liquid crystal layers, the invention is advantageous in any of TN, VA (MVA), HAN (Hybrid Aligned Nematic) and IPS (In-Plane Switching) modes.

[0106]

The use of the present mode for carrying out the invention makes it possible to provide reliable liquid crystal displays at a low cost with a high yield of manufacture. The detailed explanation is described below by using specific examples.

[Embodiment 5-1]

A liquid crystal obtained by mixing a UV-cured acrylate monomer and a methacrylate monomer (and a polymerization initiator if the reaction rate is to be improved) in an n-type chiral nematic

liquid crystal having negative dielectric constant anisotropy added with a chiral material is injected into an open cell formed by MVA type TFT and CF (color filter) substrates having no alignment film formed thereon. The cell is then irradiated with UV light from the side of the CF substrate to form polymer films that induce vertical alignment at interfaces between the substrates and the liquid crystal, thereby achieving vertical alignment.

[0107]

At this time, the vertically aligning power can be further controlled by providing the substrate surfaces with surface energy by irradiating the same with UV light (preferably, UV light having a wavelength of 360 nm or less) or performing a thermal process or chemical process (a process using an organic solvent such as NMP) on the same. The chiral material mixed in the liquid crystal also results in a certain tendency, and sufficient aligning properties can be obtained under any of d/p conditions of 0.9, 0.18 and 3.5 (where p represents the chiral pitch and d represents the cell gap).

[0108]

[Embodiment 5-2]

There is provided a reflective liquid crystal display in which reflective electrodes having unevenness are formed on a TFT substrate or a transflective liquid crystal display which has a transmissive region in part thereof. A liquid crystal obtained by mixing a UV-cured acrylate monomer and a methacrylate monomer (and a polymerization initiator if the reaction rate is to be improved) in an n-type chiral nematic liquid crystal having negative dielectric constant anisotropy added with a chiral material is

injected into an open cell formed by TFT and CF substrates having no alignment film formed thereon. The cell is then irradiated with UV light from the side of the CF substrate to form polymer films that induce vertical alignment at interfaces between the substrates and the liquid crystal, thereby achieving vertical alignment. The resultant panel is then sandwiched by circular polarization plates to provide the reflective or transreflective liquid crystal display.

[0109]

[Embodiment 5-3]

A liquid crystal display employing a color display method using color filters in three primary colors R, G and B can be provided by combining Embodiment 5-1 or 5-2 with a multi-gap technique in which at least one kind of sub-pixels among sub-pixels in R, G and B are different from others in the cell thickness. In this case, retardation $\Delta n d$ of the liquid crystal layer (Δn represents the birefringence of the liquid crystal layer and d represents the cell gap) is preferably in the range from 150 nm to 500 nm.

[0110]

A liquid crystal display according to a first embodiment of the present invention and a method of manufacturing the same as described above is summarized as follows.

[Appendix 1]

A liquid crystal display comprising:

a liquid crystal material sandwiched between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 16:

[Chemical formula 16]

X-R

(where X represents an acrylate group or a methacrylate group and R represents an organic group having a steroid skeleton); and
an ultraviolet-cured substance comprising a system including the monomer material, formed at an interface of the substrates.

[0111]

[Appendix 2]

A liquid crystal display comprising:

a liquid crystal material sandwiched between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 17:

[Chemical formula 17]

X_1-R-X_2

(where X_1 and X_2 represent an acrylate group or a methacrylate group and R represents a divalent organic group having a steroid skeleton); and

an ultraviolet-cured substance comprising a system including the monomer material, formed at an interface of the substrates.

[0112]

[Appendix 3]

A liquid crystal display comprising:

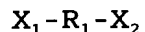
a liquid crystal material sandwiched between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 18:

[Chemical formula 18]

X-R

(where X represents an acrylate group or a methacrylate group and R represents an organic group having a steroid skeleton) and a monomer material having a structure expressed by chemical formula 19:

[Chemical formula 19]



(where X_1 and X_2 represent an acrylate group or a methacrylate group and R_1 represents a divalent organic group having a steroid skeleton); and

an ultraviolet-cured substance comprising a system including the monomer materials, formed at an interface of the substrates.

[0113]

[Appendix 4]

A method of manufacturing a liquid crystal display comprising the steps of:

sandwiching a liquid crystal material between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 20:

[Chemical formula 20]



(where X represents an acrylate group or a methacrylate group and R represents an organic group having a steroid skeleton); and

irradiating the liquid crystal material with ultraviolet rays to cure the monomer material, thereby forming an ultraviolet-cured substance at an interface of the substrate.

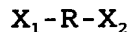
[0114]

[Appendix 5]

A method of manufacturing a liquid crystal display comprising the steps of:

sandwiching a liquid crystal material between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 21:

[Chemical formula 21]



(where X_1 and X_2 represent an acrylate group or a methacrylate group and R represents a divalent organic group having a steroid skeleton) and

irradiating the liquid crystal material with ultraviolet rays to cure the monomer material, thereby forming an ultraviolet-cured substance at an interface of the substrate.

[0115]

[Appendix 6]

A method of manufacturing a liquid crystal display comprising the steps of:

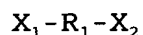
sandwiching a liquid crystal material between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 22:

[Chemical formula 22]



(where X represents an acrylate group or a methacrylate group and R represents an organic group having a steroid skeleton) and a monomer material having a structure expressed by chemical formula 23:

[Chemical formula 23]



(where X_1 and X_2 represent an acrylate group or a methacrylate group and R_1 represents a divalent organic group having a steroid skeleton); and

irradiating the liquid crystal material with ultraviolet rays to cure the monomer materials, thereby forming an ultraviolet-cured substance at an interface of the substrate.

[0116]

[Appendix 7]

A method of manufacturing a liquid crystal display according to any of appendixes 4 to 6, wherein the liquid crystal material is mixed with a material with two or more functions which has at least one ring structure and an acrylate group or a methacrylate group at an end thereof.

[0117]

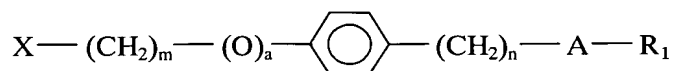
A liquid crystal display according to a second embodiment of the present invention and a method of manufacturing the same as described above is summarized as follows.

[Appendix 8]

A liquid crystal display comprising:

a liquid crystal material sandwiched between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 24:

[Chemical formula 24]



(where X represents an acrylate group or methacrylate group; A represents a benzene ring or cyclohexane ring; R represents an alkyl group or alkoxy group having carbon atoms in a quantity in

the range from 1 to 20; a represents 0 or 1; m represents an integral number in the range from 0 to 10; and n represents an integral number in the range from 0 to 2); and

an ultraviolet-cured substance comprising a system including the monomer material, formed at an interface of the substrates.

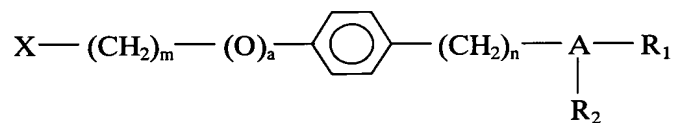
[0118]

[Appendix 9]

A liquid crystal display comprising:

a liquid crystal material sandwiched between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 25:

[Chemical formula 25]



(where X represents an acrylate group or methacrylate group; A represents a benzene ring or cyclohexane ring; R₁ represents an alkyl group or alkoxy group having carbon atoms in a quantity in the range from 1 to 20; R₂ represents CH₃ or a fluorine atom; a represents 0 or 1; m represents an integral number in the range from 0 to 10; and n represents an integral number in the range from 0 to 2); and

an ultraviolet-cured substance comprising a system including the monomer material, formed at an interface of the substrates.

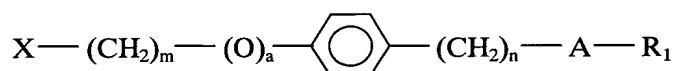
[0119]

[Appendix 10]

A method of manufacturing a liquid crystal display comprising the steps of:

sandwiching a liquid crystal material between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 26:

[Chemical formula 26]



(where X represents an acrylate group or methacrylate group; A represents a benzene ring or cyclohexane ring; R represents an alkyl group or alkoxy group having carbon atoms in a quantity in the range from 1 to 20; a represents 0 or 1; m represents an integral number in the range from 0 to 10; and n represents an integral number in the range from 0 to 2); and

irradiating the liquid crystal material with ultraviolet rays to cure the monomer materials, thereby forming an ultraviolet-cured substance at an interface of the substrate.

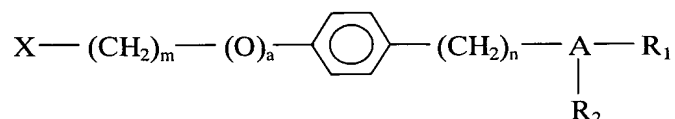
[0120]

[Appendix 11]

A method of manufacturing a liquid crystal display comprising the steps of:

sandwiching a liquid crystal material between substrates, wherein the liquid crystal material includes a monomer material having a structure expressed by chemical formula 27:

[Chemical formula 27]



(where X represents an acrylate group or methacrylate group; A represents a benzene ring or cyclohexane ring; R_1 represents an alkyl group or alkoxy group having carbon atoms in a quantity in the range from 1 to 20; R_2 represents CH_3 or a fluorine atom; a represents 0 or 1; m represents an integral number in the range from 0 to 10; and n represents an integral number in the range from 0 to 2); and

irradiating the liquid crystal material with ultraviolet rays after being sandwiched between the substrates to cure the monomer materials, thereby forming an ultraviolet-cured substance at an interface of the substrate.

[0121]

[Appendix 12]

A method of manufacturing a liquid crystal display according to appendix 10 or 11, wherein $n = 0$.

[0122]

[Appendix 13]

A method of manufacturing a liquid crystal display according to any of appendixes 10 to 12, wherein $a = 0$.

[0123]

[Appendix 14]

A method of manufacturing a liquid crystal display according to any of appendixes 10 to 13, wherein the sum of the number of carbon atoms of the group R_1 and the integral number m is in the range from 5 to 20.

[0124]

[Appendix 15]

A method of manufacturing a liquid crystal display according

to any of appendixes 10 to 14, wherein the liquid crystal material is mixed with a material with two or more functions which has at least one ring structure and an acrylate group or a methacrylate group at an end thereof.

[0125]

[Appendix 16]

A liquid crystal display according to any of appendixes 1, 2, 3, 8 and 9, wherein the liquid crystal material has negative dielectric constant anisotropy, the display comprising a structure for regulating alignment formed therein.

[0126]

A liquid crystal display according to a third embodiment of the present invention and a method of manufacturing the same as described above is summarized as follows.

[Appendix 17]

A method of manufacturing a liquid crystal display, comprising the steps of:

sandwiching a liquid crystal material including a polymeric material between substrates; and

irradiating the gap between the substrates with diffuse light to form an alignment control film.

[0127]

[Appendix 18]

A method of manufacturing a liquid crystal display, comprising the steps of:

sandwiching a liquid crystal material including a polymeric material between substrates; and

performing scan-irradiation of the gap between the

substrates to form an alignment control film.

[0128]

[Appendix 19]

A method of manufacturing a liquid crystal display, comprising the steps of:

sandwiching a liquid crystal material including a polymeric material between substrates; and

performing scan-irradiation of the gap between the substrates with diffuse light to form an alignment control film.

[0129]

[Appendix 20]

A method of manufacturing a liquid crystal display according to any of appendixes 17 to 19, wherein the dose of irradiation at the time of formation of the alignment control film is in the range from 8000 mJ/cm² to 30000 mJ/cm².

[0130]

[Appendix 21]

A method of manufacturing a liquid crystal display according to any of appendixes 17 to 20, wherein multi-step irradiation is performed with the intensity of irradiation varied at the time of formation of the alignment control film.

[0131]

[Appendix 22]

A method of manufacturing a liquid crystal display according to any of appendixes 17 to 21, wherein the intensity of light having a wavelength in the range from 200 nm to 330 nm is in the range from 0 to 20 % of the intensity of light having a wavelength in the range from 200 nm to 800 nm at the time of formation of the

alignment control film.

[012]

[Appendix 23]

A method of manufacturing a liquid crystal display according to any of appendixes 17 to 22, comprising the step of performing a plasma process or excimer UV process as a surface modifying process on a surface of at least either of the substrates before the liquid crystal material is injected.

[0133]

[Appendix 24]

A method of manufacturing a liquid crystal display according to any of appendixes 17 to 23, comprising the step of applying a voltage to an electrode formed on the substrates or heating the substrates when the liquid crystal material is injected between the substrates, thereby preventing the polymeric material from being absorbed onto the surface of the substrates.

[0134]

[Appendix 25]

A method of manufacturing a liquid crystal display according to any of appendixes 17 to 24, comprising the step of providing a horizontally aligning spacer between the substrates.

[0135]

[Appendix 26]

A method of manufacturing a liquid crystal display according to appendix 25, wherein the surface tension of the horizontally aligning spacer is 40 dyn/cm or more.

[0136]

[Appendix 27]

A method of manufacturing a liquid crystal display according to any of appendixes 17 to 26, wherein a visible light sealing material is used.

[0137]

[Appendix 28]

A method of manufacturing a liquid crystal display according to any of appendixes 17 to 27, comprising the step of performing a process of pressing the substrate before or after the irradiation with light.

[0138]

A liquid crystal display according to a fourth embodiment of the present invention and a method of manufacturing the same as described above is summarized as follows.

[Appendix 29]

A liquid crystal display comprising:

a liquid crystal material sealed between a pair of substrates;

wherein the liquid crystal material comprises a fluorine type liquid crystal having negative dielectric constant anisotropy and an alignment assisting material for vertically aligning liquid crystal molecules;

the alignment assisting material comprises a monofunctional monomer and a multifunctional monomer of acrylic acid type or methacrylic acid type in a mixing ratio by weight in the range from 15:1 to 5:1, and a polymerization initiator which is in a mixing ratio of 2 % or less by weight to the total amount of the monofunctional monomer and the multifunctional monomer; and

the mixing ratio by weight between the liquid crystal material and the alignment assisting material is in the range from 99:1 to 90:10.

[0139]

[Appendix 30]

A liquid crystal display according to appendix 29, wherein the alignment assisting material has photo-curing properties.

[0140]

[Appendix 31]

A liquid crystal display according to appendix 30, wherein the alignment assisting material is cured by light having a wavelength of about 365 nm with an irradiation energy in the range from 6 J/cm² to 50 J/cm².

[0141]

[Appendix 32]

A liquid crystal display according to appendix 30, wherein the alignment assisting material is cured by intensity of 30 mW/cm² or less at least at the beginning of irradiation.

[0142]

[Appendix 33]

A liquid crystal display according to appendix 29, wherein the monofunctional monomer is liquid at the room temperature and under a normal pressure.

[0143]

[Appendix 34]

A liquid crystal display according to appendix 29, wherein the purity of the monofunctional monomer and the multifunctional monomer is 98.5 % or more.

[0144]

[Appendix 35]

A liquid crystal display according to any of appendixes 29 to 34, wherein the amount of the polymerization initiator is 0 %.

[0145]

[Appendix 36]

A liquid crystal display according to any of appendixes 29 to 35, wherein an unreacted residue of the monofunctional monomer exists in the mixed liquid crystal, and an unreacted residue of the multifunctional monomer and the polymerization initiator is 10 % or less.

[0146]

[Appendix 37]

A liquid crystal display according to appendix 36, wherein the ratio of unreacted part of the monofunctional monomer is 50 % or less.

[0147]

[Appendix 38]

A liquid crystal display according to any of appendixes 29 to 37, wherein either of the pair of substrates has an active element and a color filter layer, and the other substrate is formed with no light-blocking member in a display area thereof.

[0148]

[Appendix 39]

A liquid crystal display according to appendix 38, wherein the other substrate constitutes a surface irradiated with light for curing the alignment assisting material.

[0149]

[Appendix 40]

A liquid crystal display according to any of appendixes 29 to 38, wherein the polymerization initiator exhibits light-absorbing properties in the region of visible light.

[0150]

[Appendix 41]

A liquid crystal display according to any of appendixes 29 to 40, wherein the mixed liquid crystal is injected using a dispenser injection method, and no liquid crystal injection hole is provided on a seal material for sealing the mixed liquid crystal between the pair of substrates.

[0151]

[Appendix 42]

A method of manufacturing a liquid crystal display comprising the steps of:

sealing a liquid crystal material between a pair of substrates;

wherein the liquid crystal material comprises a fluorine type liquid crystal having negative dielectric constant anisotropy and an alignment assisting material for vertically aligning liquid crystal molecules;

the alignment assisting material comprises a monofunctional monomer and a multifunctional monomer of acrylic acid type or methacrylic acid type in a mixing ratio by weight in the range from 15:1 to 5:1, and a polymerization initiator which is in a mixing ratio of 2 % or less by weight to the total amount of the monofunctional monomer and the multifunctional monomer;

the mixing ratio by weight between the liquid crystal

material and the alignment assisting material is in the range from 99:1 to 90:10; and

curing the alignment assisting material at an interface of the substrates to align the liquid crystal molecules vertically.

[0152]

[Appendix 43]

A method of manufacturing a liquid crystal display according to appendix 42, wherein the mixed liquid crystal is injected using a dispenser injection method.

[0153]

[Appendix 44]

A method of manufacturing a liquid crystal display according to appendix 41 or 43, wherein the mixed liquid crystal dispensed using the dispenser injection method comprises different materials which are used depending on dispensing positions on the substrates.

[0154]

[Appendix 45]

A method of manufacturing a liquid crystal display according to appendix 44, wherein the dispensed mixed liquid crystal is prepared by dispensing, in combination, at least two among the liquid crystal material alone including no alignment assisting material, a liquid crystal which is a mixture of the liquid crystal material and the monofunctional monomer, a liquid crystal which is a mixture of the liquid crystal material and the bifunctional monomer, a liquid crystal which is a mixture of the liquid crystal material, the monofunctional monomer, and the bifunctional monomer and a liquid crystal which is a mixture of the liquid crystal material and the polymerization initiator.

[0155]

A liquid crystal display according to a fifth embodiment of the present invention and a method of manufacturing the same as described above is summarized as follows.

[Appendix 46]

A liquid crystal display comprising:

a chiral nematic liquid crystal having negative dielectric constant anisotropy sealed between a pair of substrates; and

an alignment control section formed by irradiating a monomer, oligomer or polymer having at least one kind of functional group mixed in a liquid crystal layer with an electromagnetic wave and causing a reaction of the same such that the longitudinal direction of liquid crystal molecules becomes substantially perpendicular to either of the substrates when no voltage is applied.

[0156]

[Appendix 47]

A liquid crystal display according to appendix 46, wherein a reflective electrode is formed on either of the pair of substrates.

[0157]

[Appendix 48]

A liquid crystal display according to appendix 46 or 47, wherein either linear polarizer or circular polarizer is provided on both of the pair of substrates or wherein the linear polarizer is provided on either of the substrates and the circular polarizer is provided on the other.

[0158]

[Appendix 49]

A liquid crystal display according to any of appendixes 46

to 48, wherein at least any one of three sub-pixels in which any of color filters in R, G and B is formed is different from others in the cell thickness.

[0159]

[Appendix 50]

A liquid crystal display according to any of appendixes 46 to 49, wherein the product $\Delta n d$ of birefringence Δn of the liquid crystal and the thickness d of the liquid crystal layer is in the range from 150 nm to 500 nm.

[0160]

[Effect of the Invention]

As described above, the invention makes it possible to omit the existing step of forming a vertical alignment film and to thereby allow a cost reduction.

The invention also makes it possible to form a vertical alignment film easily even if the mother glass is large.

The invention further makes it possible to reduce white lines and to thereby suppress any reduction in contrast.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1]

It is a perspective view showing a schematic configuration of an MVA type liquid crystal display.

[Fig. 2]

It is a plan view showing the schematic configuration of the MVA type liquid crystal display.

[Fig. 3]

It is a view showing a basic principle 1 of a liquid crystal display and a method of manufacturing the same in a first mode

for carrying out the invention.

[Fig. 4]

It is a view showing a basic principle 2 of a liquid crystal display and a method of manufacturing the same in the first mode for carrying out the invention.

[Fig. 5]

It is a view showing examples of monofunctional monomer materials having a steroid skeleton to be mixed in a liquid crystal material of a liquid crystal display in the first mode for carrying out the invention.

[Fig. 6]

It is a view showing examples of bifunctional monomer materials having a ring structure to be mixed in a liquid crystal material of a liquid crystal display in the first mode for carrying out the invention.

[Fig. 7]

It is a view showing changes in the voltage holding ratio and the state of alignment depending on the mixing ratio of a monomer material mixed in a liquid crystal material of a liquid crystal display in the first mode for carrying out the invention.

[Fig. 8]

It is a view showing examples of divalent organic groups having a steroid skeleton mixed in a liquid crystal material of a liquid crystal display in the first mode for carrying out the invention.

[Fig. 9]

It is a view showing changes in the voltage holding ratio and the state of alignment depending on the mixing ratio of a monomer

material mixed in a liquid crystal material of a liquid crystal display in the first mode for carrying out the invention.

[Fig. 10]

It is a view showing examples of monofunctional monomer materials mixed in a liquid crystal material of a liquid crystal display in a second mode for carrying out the invention.

[Fig. 11]

It is a view showing examples of monomer materials having a ring structure mixed in a liquid crystal material of a liquid crystal display in the second mode for carrying out the invention.

[Fig. 12]

It is a view showing a phenomenon in which horizontally aligned domains appearing as white lines are generated in a vertically aligned region.

[Fig. 13]

It is a view showing examples of monofunctional monomer materials mixed in a liquid crystal material of a liquid crystal display in the second mode for carrying out the invention.

[Fig. 14]

It is a view showing changes in the voltage holding ratio and the state of alignment depending on the mixing ratio of a monomer material mixed in a liquid crystal material of a liquid crystal display in the second mode for carrying out the invention.

[Fig. 15]

It is a view showing a reduction of horizontally aligned domains visually perceived as white line in a vertically aligned region which is achieved by a method of manufacturing a liquid crystal display in a third mode for carrying out the invention.

[Fig. 16]

It is a view showing a relationship between doses of irradiation and voltage holding ratios in the method of manufacturing a liquid crystal display in the third mode for carrying out the invention.

[Fig. 17]

It is a view briefly showing LCD manufacturing processes according to the related art.

[Fig. 18]

It is a view schematically showing a method of forming an alignment control layer after injecting a liquid crystal.

[Fig. 19]

It is a view showing display irregularities which are observed when a liquid crystal display panel of a 15-inch type active matrix LCD is turned on.

[Fig. 20]

It is a graph showing a comparison between voltage-transmittance (gradation transmittance) characteristics of normal and abnormal parts at liquid crystal injection holes in the case of storage driving.

[Fig. 21]

It is a view showing the problem of display irregularities at liquid crystal injection holes using large panels (equivalent to a 15-inch type) for evaluation of voltage holding ratios which are formed by combining a pair of substrates having transparent electrodes.

[Fig. 22]

It is a view showing a relationship between a UV irradiation

step for a liquid crystal cell in a fourth mode for carrying out the invention and voltage holding ratios.

[Fig. 23]

It is a view for explaining how the specific resistance of a liquid crystal material is reduced by additives that are substances constituting alignment assisting materials mixed in the liquid crystal.

[Fig. 24]

It shows a result of an examination of changes in voltage holding ratios relative to doses of irradiation light in the vicinity of a liquid crystal injection hole of a liquid crystal cell in the fourth mode for carrying out the invention, the examination being performed with the amount of a bifunctional monomer varied.

[Fig. 25]

It shows a result of an examination of changes in voltage holding ratios relative to doses of irradiation light at a central part of the liquid crystal cell in the fourth mode for carrying out the invention, the examination being performed with the amount of the bifunctional monomer varied.

[Fig. 26]

It is a graph showing a comparison between voltage holding ratios at the liquid crystal injection hole of the liquid crystal cell in the fourth mode for carrying out the invention, the holding ratios being achieved by increasing the amount of the bifunctional monomer B shown in Fig. 23 and increasing the purity of the monofunctional monomer D, respectively.

[Fig. 27]

It is a graph showing a comparison between voltage holding ratios at the central part of the liquid crystal cell in the fourth mode for carrying out the invention, the holding ratios being achieved by increasing the amount of the bifunctional monomer B shown in Fig. 23 and increasing the purity of the monofunctional monomer D, respectively.

[Fig. 28]

It is a view showing differences between voltage holding ratios at the liquid crystal injection hole of the liquid crystal cell in the fourth mode for carrying out the invention depending on the presence and absence of the polymerization initiator, the amount of the bifunctional monomer B being increased from that in Fig. 23.

[Fig. 29]

It shows a result of an examination of changes in voltage holding ratios relative to doses of irradiation light at the central part of the liquid crystal cell in the fourth mode for carrying out the invention depending on the presence and absence of the polymerization initiator, the amount of the bifunctional monomer B being increased from that in Fig. 23.

[Fig. 30]

It is a view showing a result of an examination on a relationship between the purity of a monofunctional monomer and voltage holding ratios at the injection hole of the liquid crystal cell in the fourth mode for carrying out the invention.

[Fig. 31]

It is a view showing a result of an examination on a relationship between irradiation energy and voltage holding ratios

of the liquid crystal cell in the fourth mode of carrying out the invention depending on differences in purity between monofunctional monomers D, the examination having been conducted under the same conditions in Fig. 30 except that the amount of the bifunctional monomers B was increased by a factor of 2.4.

[Fig. 32]

It is a graph of the liquid crystal cell in the fourth mode for carrying out the invention in which the purity (GC %) of monofunctional monomers D are plotted along the abscissa axis and voltage holding ratios (%) are plotted along the ordinate axis.

[Fig. 33]

It shows a section of a liquid crystal panel suitable for use in the fourth mode for carrying out the invention.

[Fig. 34]

It shows a section of a liquid crystal panel suitable for use in the fourth mode for carrying out the invention.

[Fig. 35]

It is a view showing steps of manufacturing a liquid crystal display panel by employing a dispenser injection method suitable for use in the fourth mode for carrying out the invention.

[Fig. 36]

It is a view showing manufacture of a liquid crystal panel by dispensing two or more kinds of mixed liquid crystals instead of one kind of mixed liquid crystal by employing a dispenser injection method suitable for use in the fourth mode for carrying out the invention.

[Legend]

2 monofunctional monomer

2a, 3a hydrophobic skeleton
2b, 3b photoreactive group
4 polymer film
5 liquid crystal material
10 liquid crystal display panel
12 seal material
14 liquid crystal injection hole
16 display irregularity
21, 22 glass substrate
30, 30' alignment film
31 seal material
32 color filter
33 active elements
34 pixel electrodes
35 opposite electrode
61, 62 protrusions

FIG.1(a)

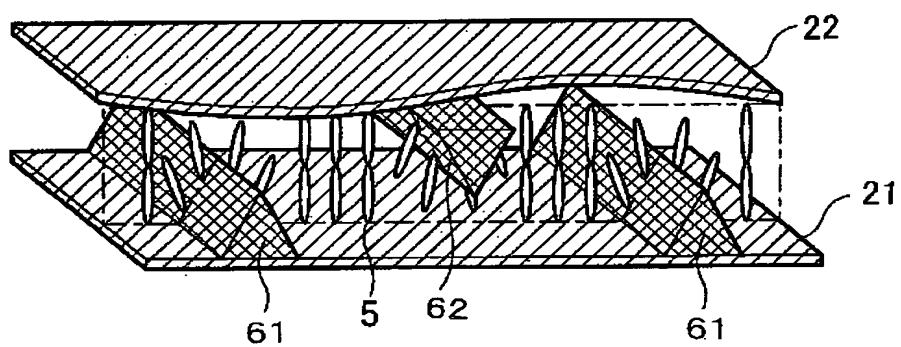


FIG.1(b)

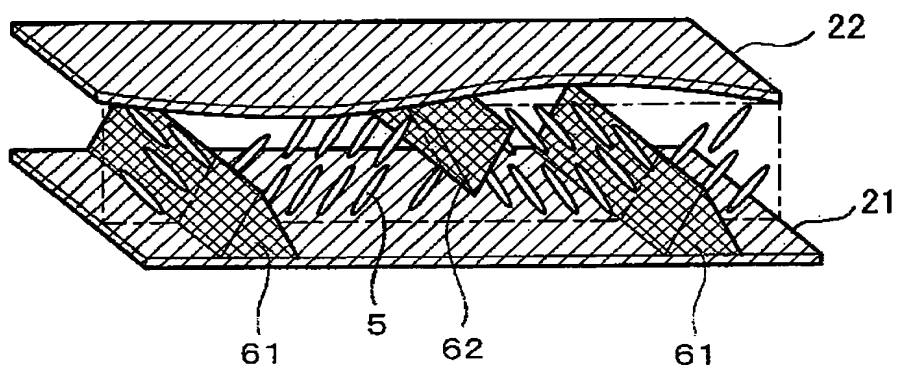
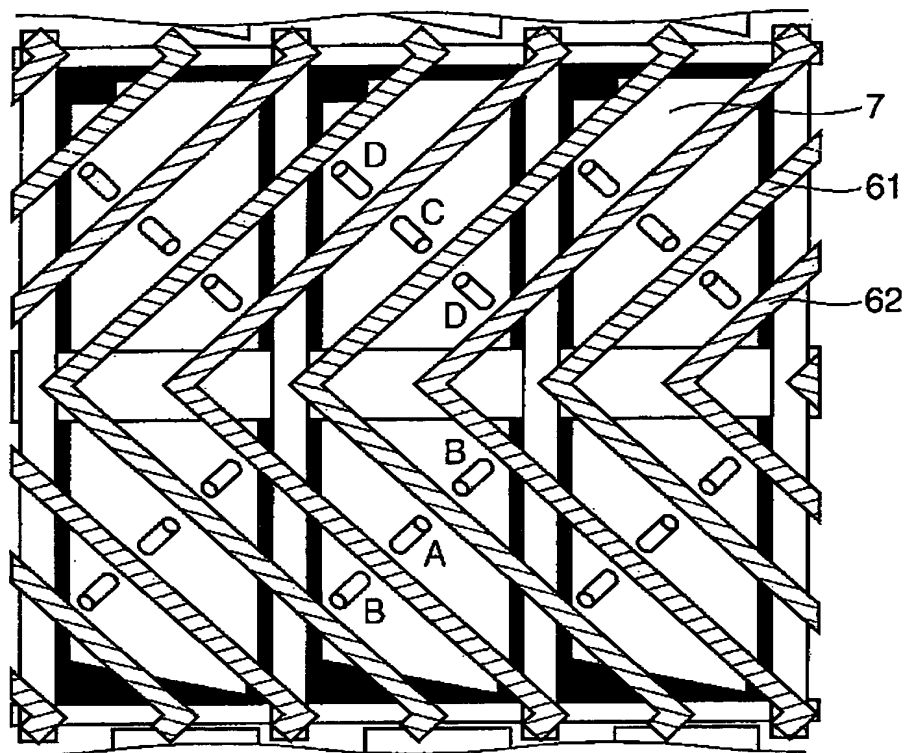


FIG.2



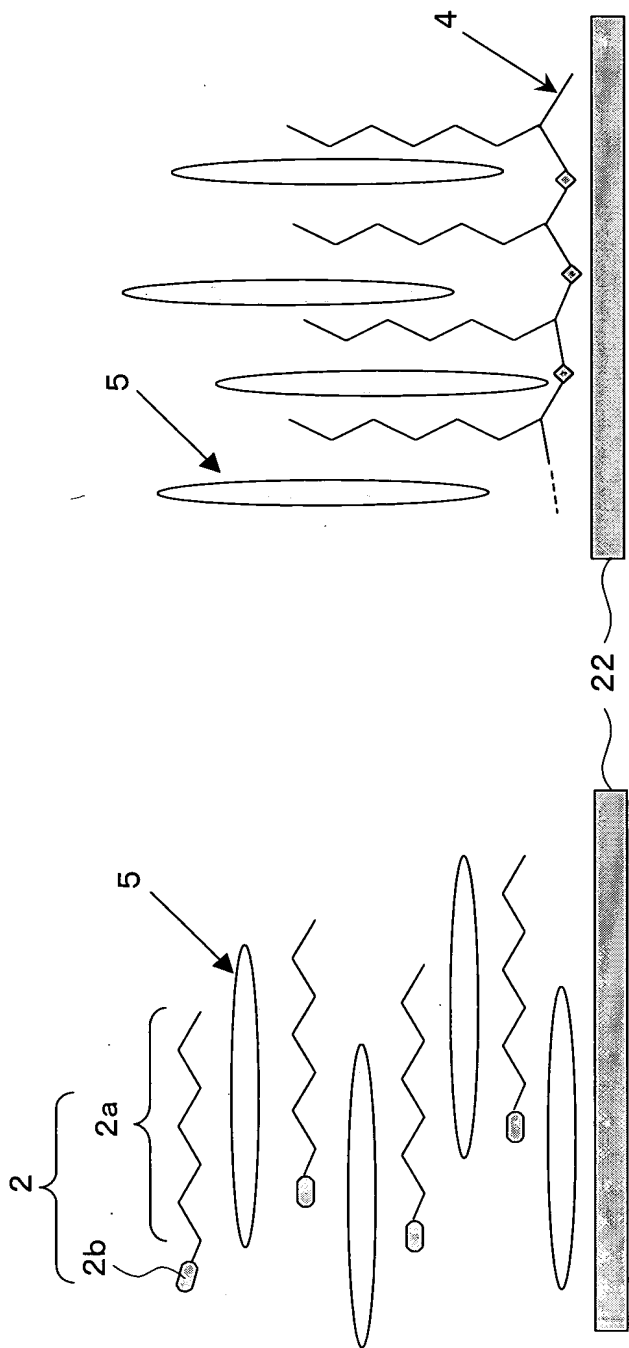


FIG.3(a)

FIG.3(b)

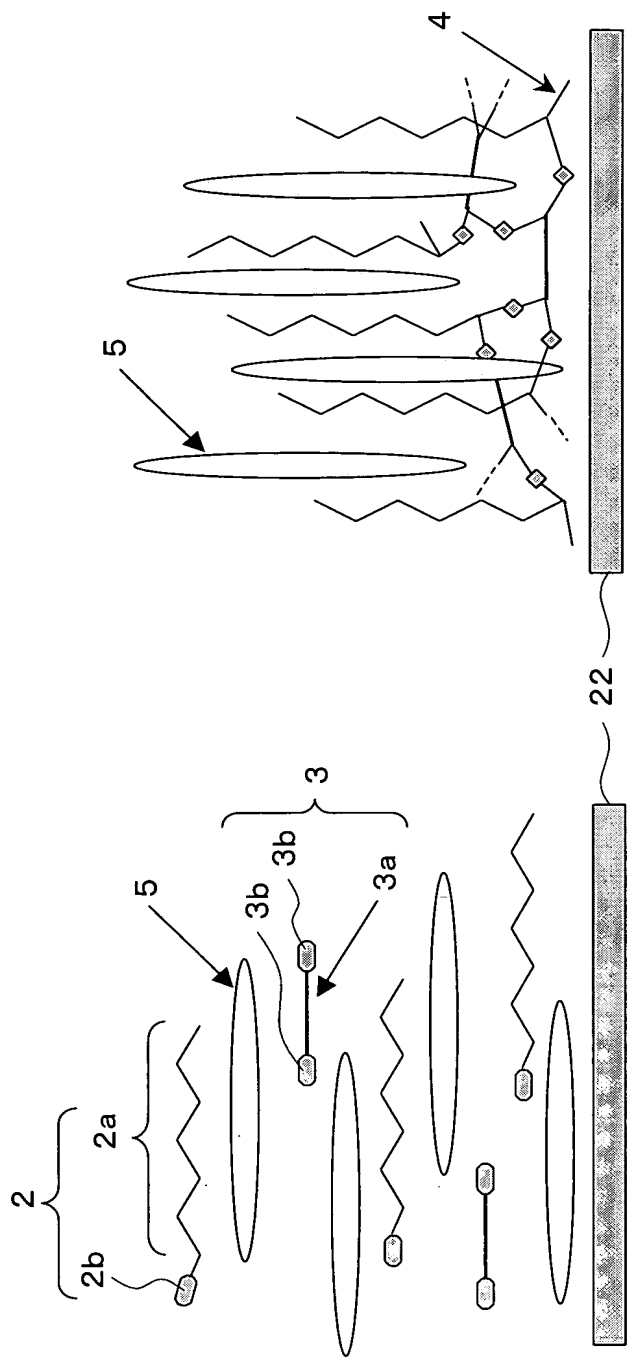


FIG.4(a)

FIG.4(b)

FIG. 5(a)

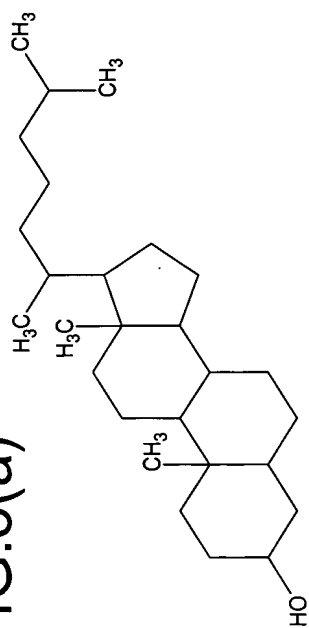


FIG. 5(c)

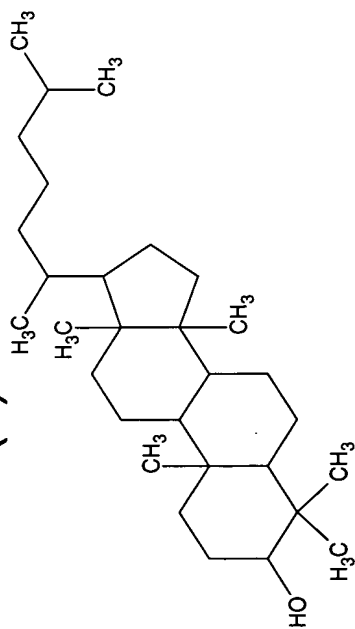


FIG. 5(b)

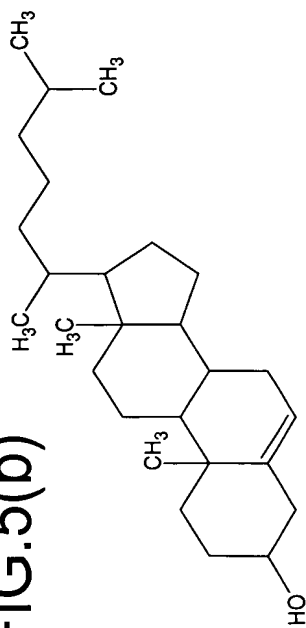
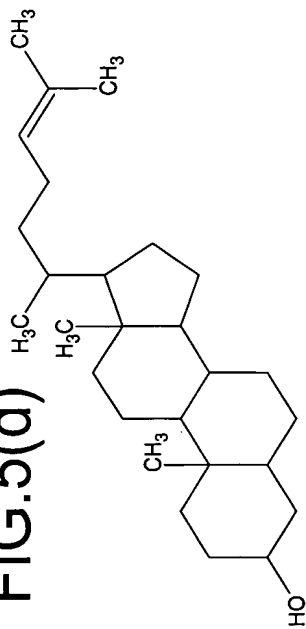


FIG. 5(d)



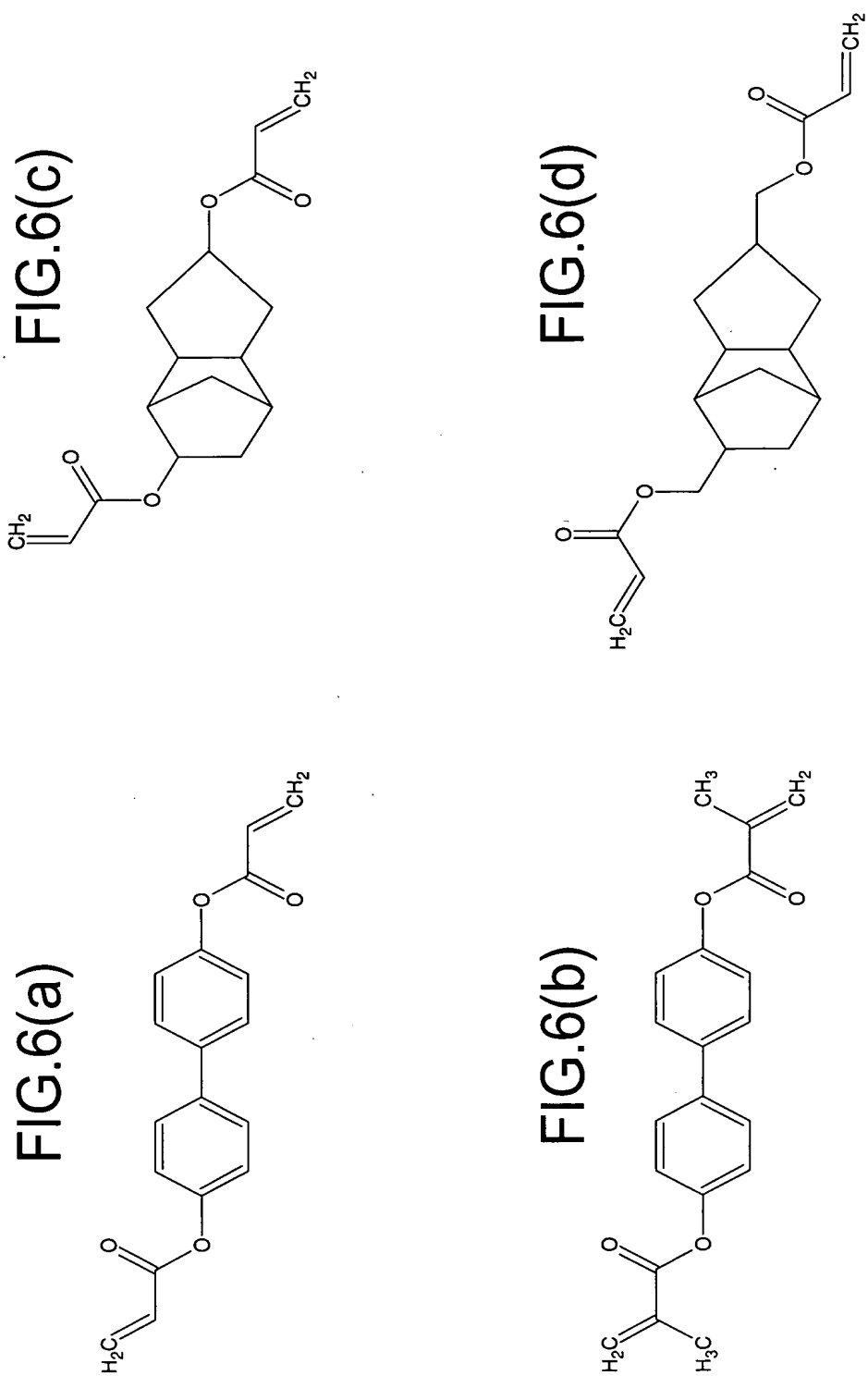


FIG.7

O: VERTICAL ALIGNMENT IS ACHIEVED
 Δ : HORIZONTAL ALIGNMENT REMAINS IN PART
 \times : HORIZONTAL ALIGNMENT REMAINS AS IT IS

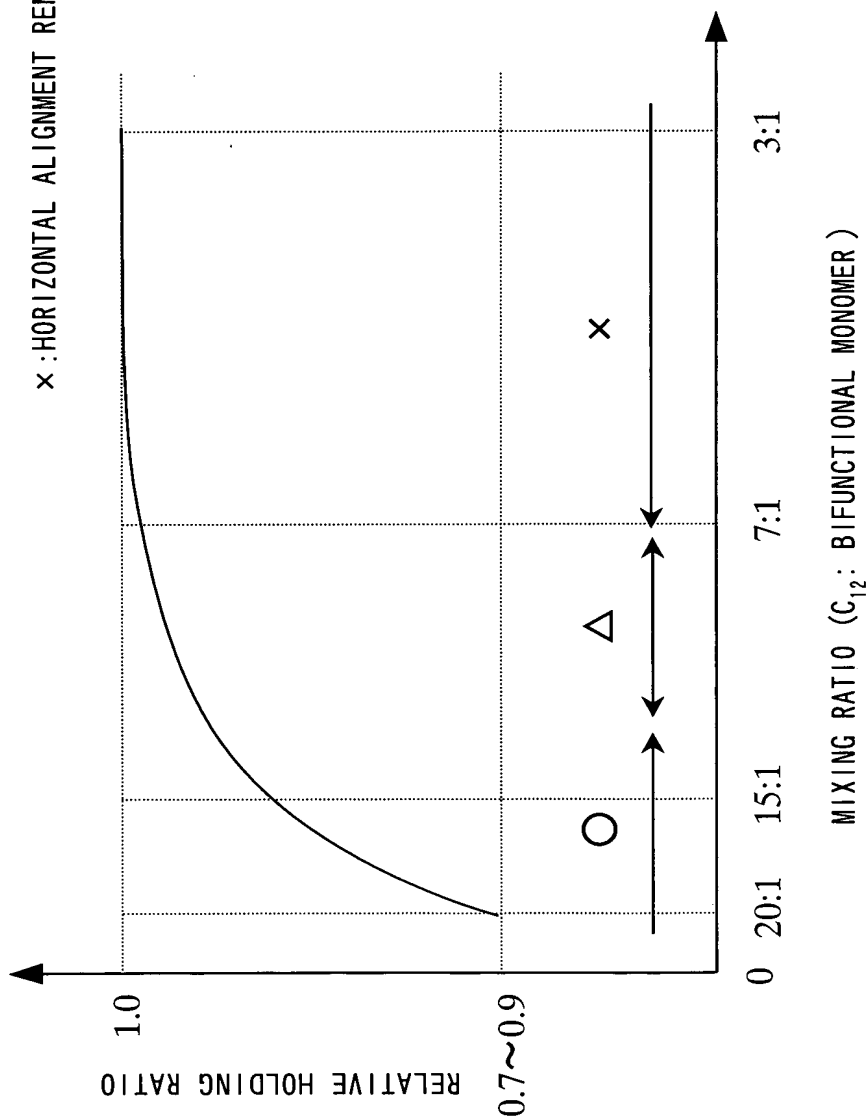


FIG.8(a)

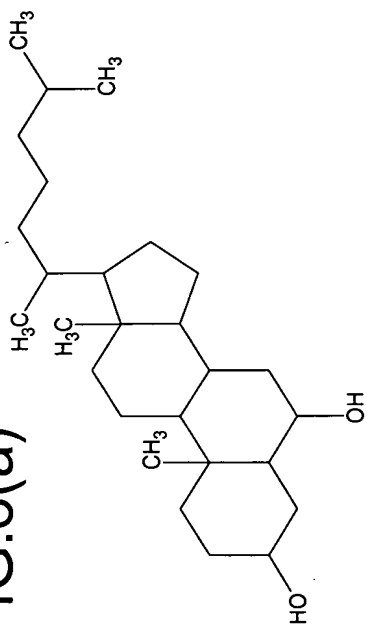


FIG.8(c)

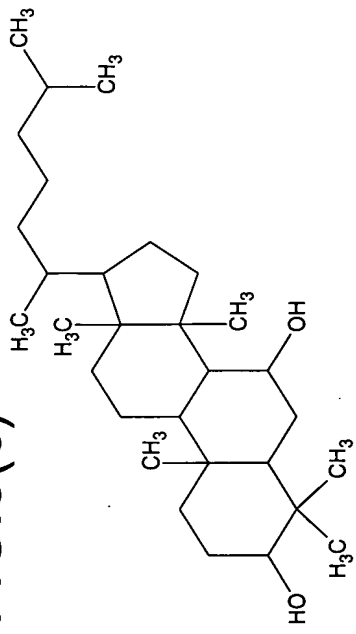


FIG.8(b)

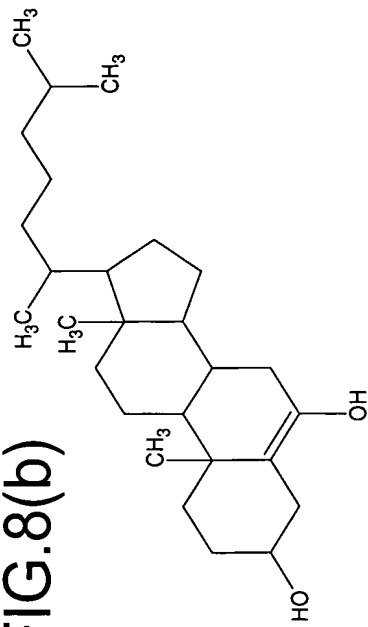
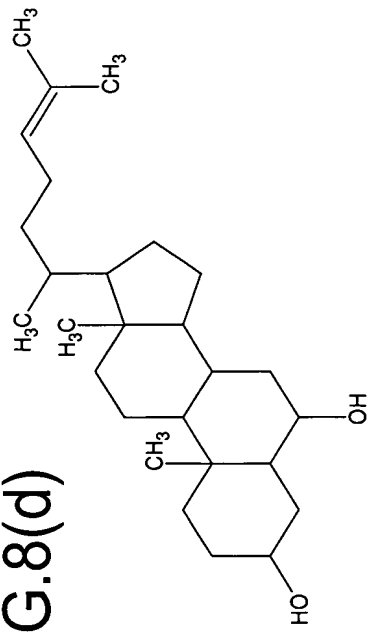


FIG.8(d)



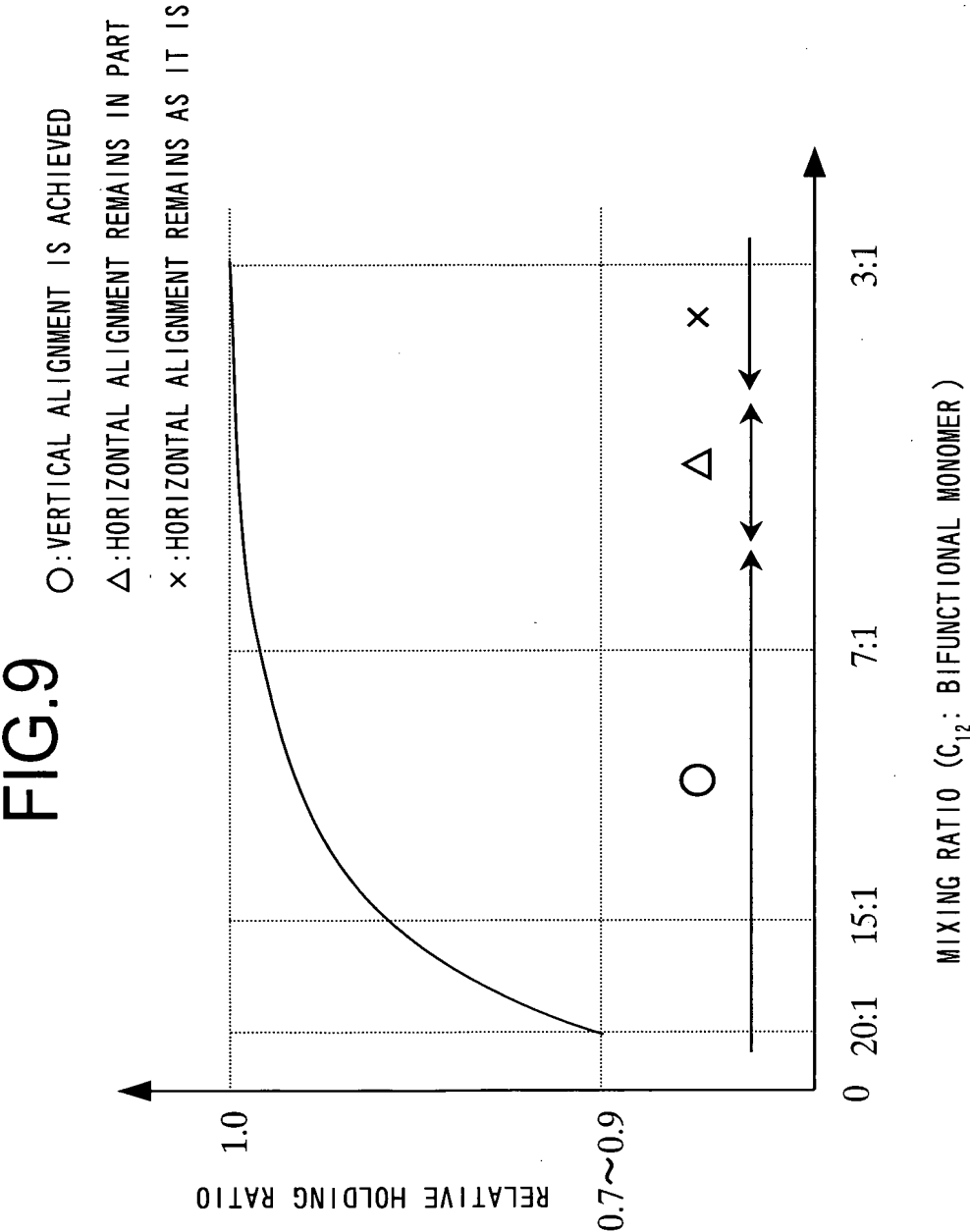


FIG.10(a)

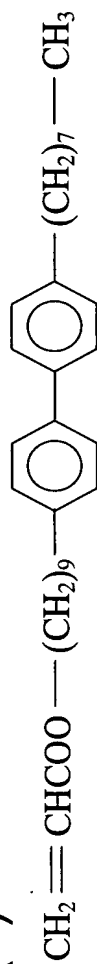


FIG.10(b)

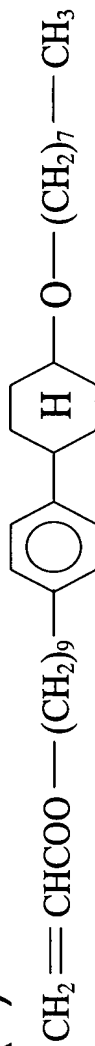


FIG.10(c)

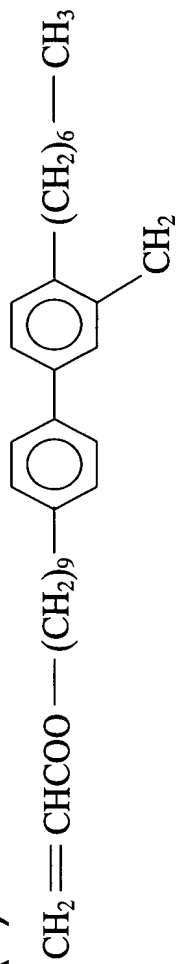


FIG.10(d)

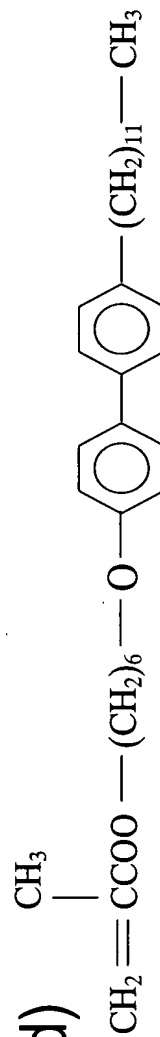


FIG. 11(a)

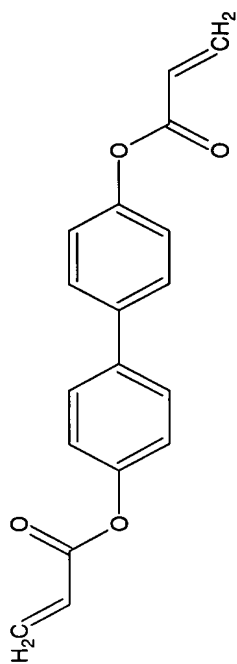


FIG. 11(c)

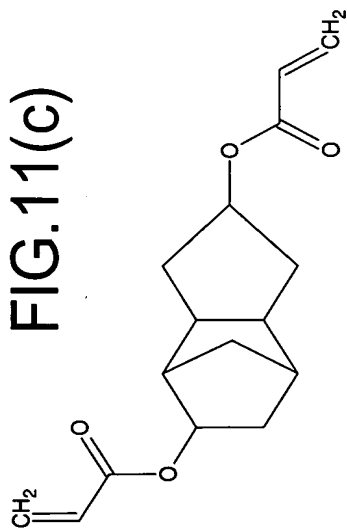


FIG. 11(b)

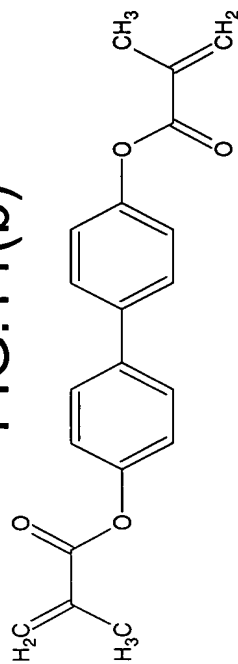


FIG. 11(d)

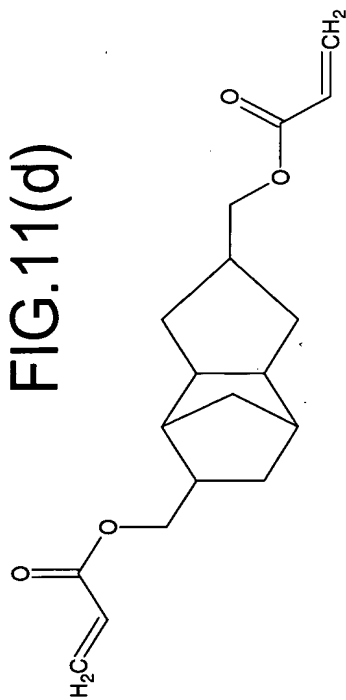
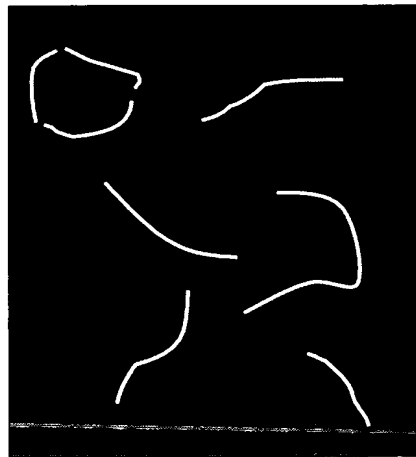


FIG.12(a)



ABOUT 0.1mm

EXAMPLE OF RELATED ART

FIG.12(b)



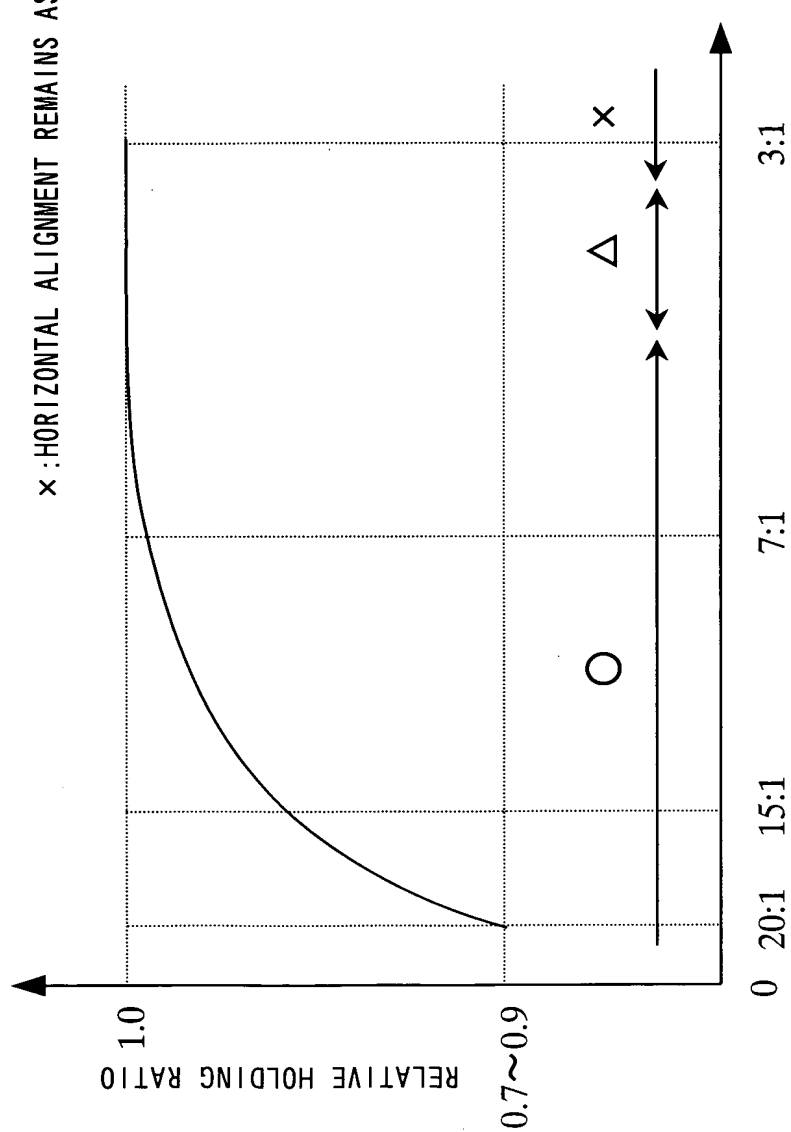
ABOUT 0.1mm

ART FIRST MODE OF INVENTION



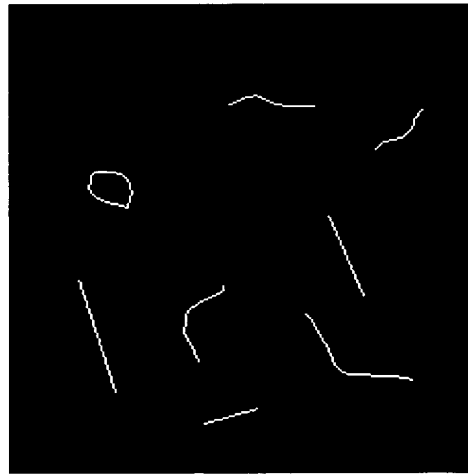
FIG.14

○: VERTICAL ALIGNMENT IS ACHIEVED
 △: HORIZONTAL ALIGNMENT REMAINS IN PART
 ×: HORIZONTAL ALIGNMENT REMAINS AS IT IS



MIXING RATIO (MONOMER MATERIAL OF EMBODIMENT: BIFUNCTIONAL MONOMER)

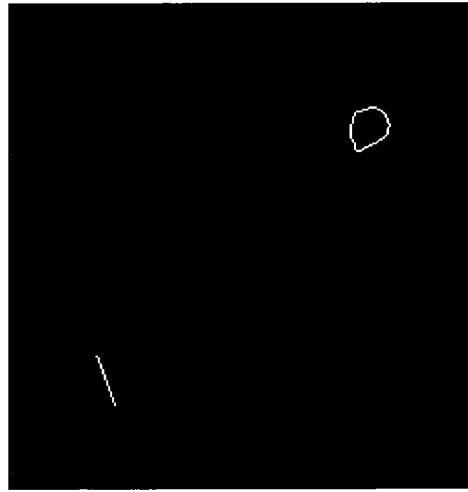
FIG.15(a)



$100\ \mu\text{m}$

IRRADIATION WITH PARALLEL LIGHT

FIG.15(b)



$100\ \mu\text{m}$

IRRADIATION WITH DIFFUSE LIGHT

FIG.16

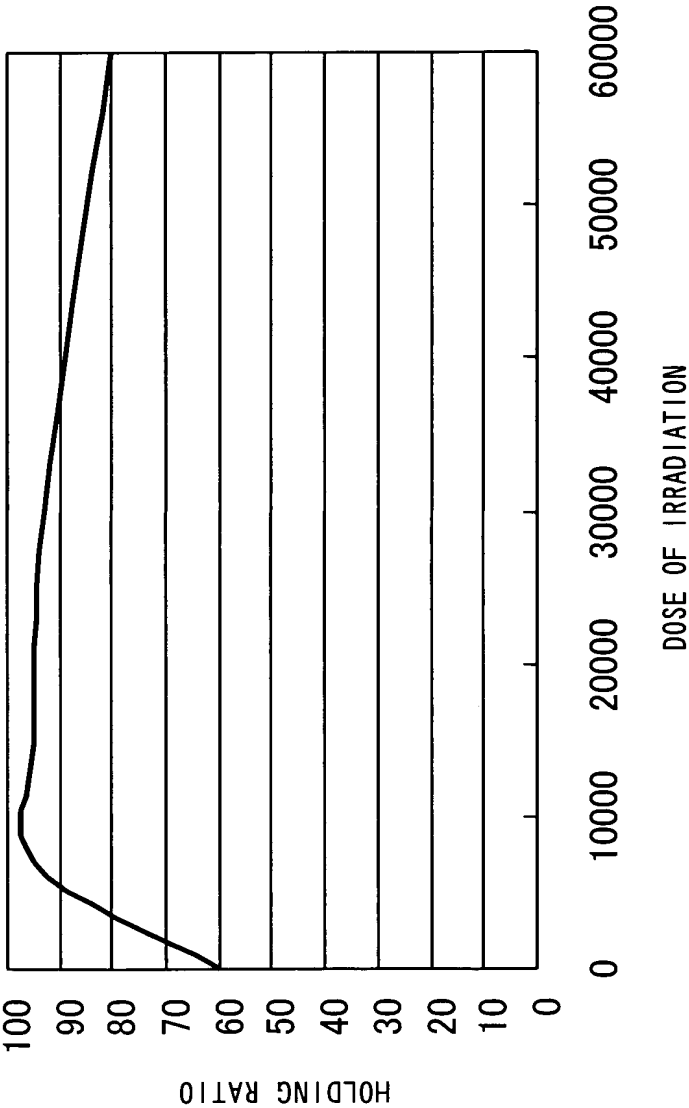


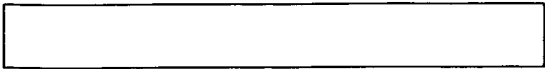
FIG.17(a)  21


FIG.17(b)  30 21

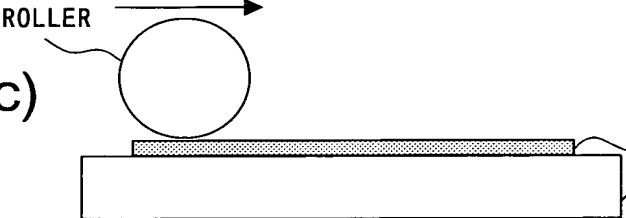
FIG.17(c)  ROLLER 30 21

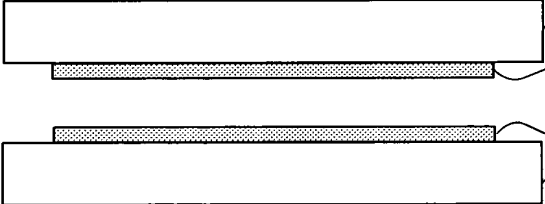
FIG.17(d)  22 30 21

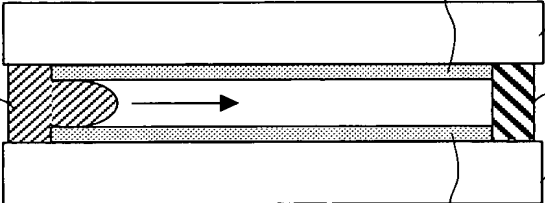
FIG.17(e)  30 22 5 31 21

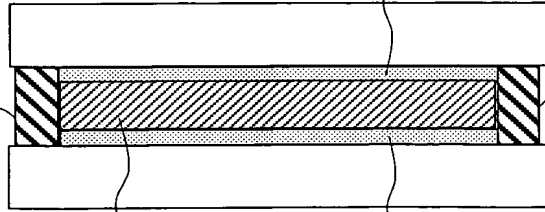
FIG.17(f)  30 22 31 5 30 21

FIG.18(a)



↓ ↓ ↓ ↓
UV LIGHT

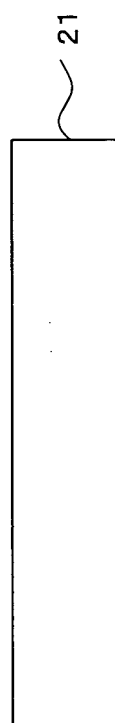


FIG.18(b-1)

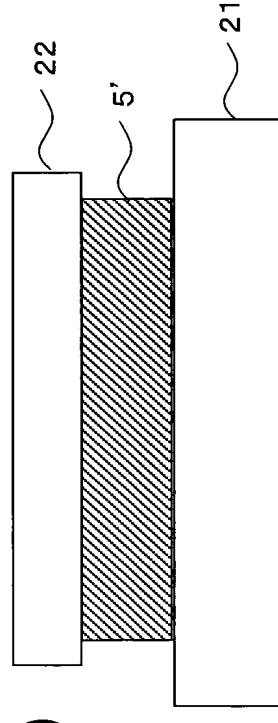


FIG.18(b)

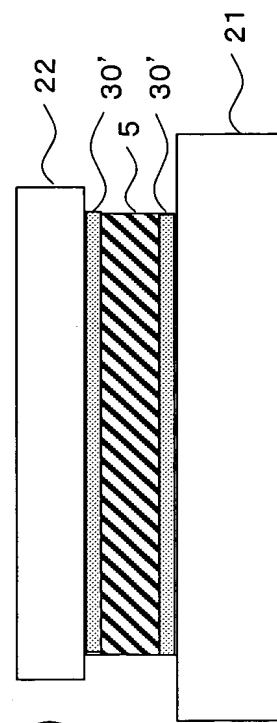


FIG.18(c)

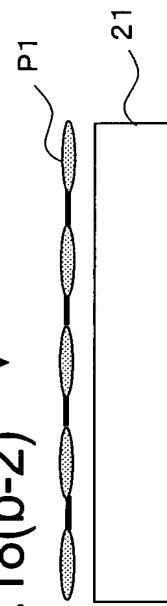
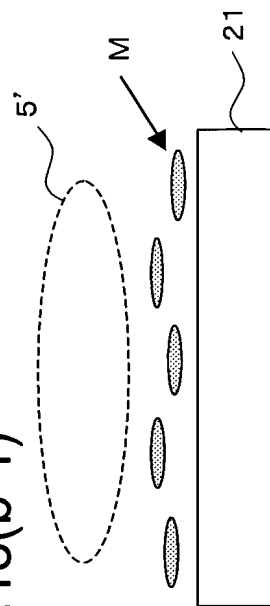


FIG.18(b-2)

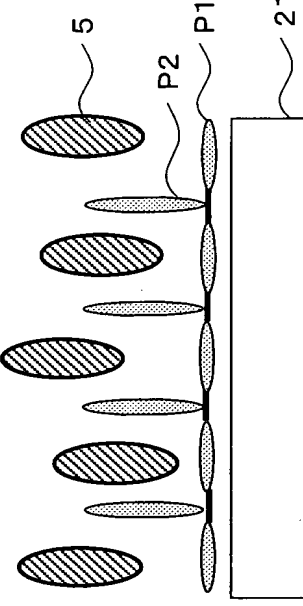


FIG.18(b-3)

FIG.19

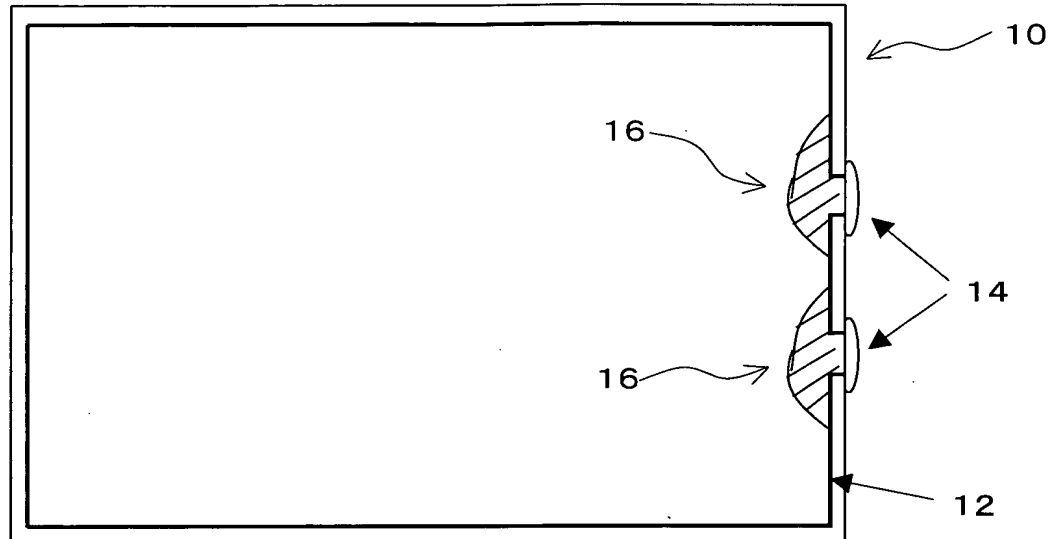
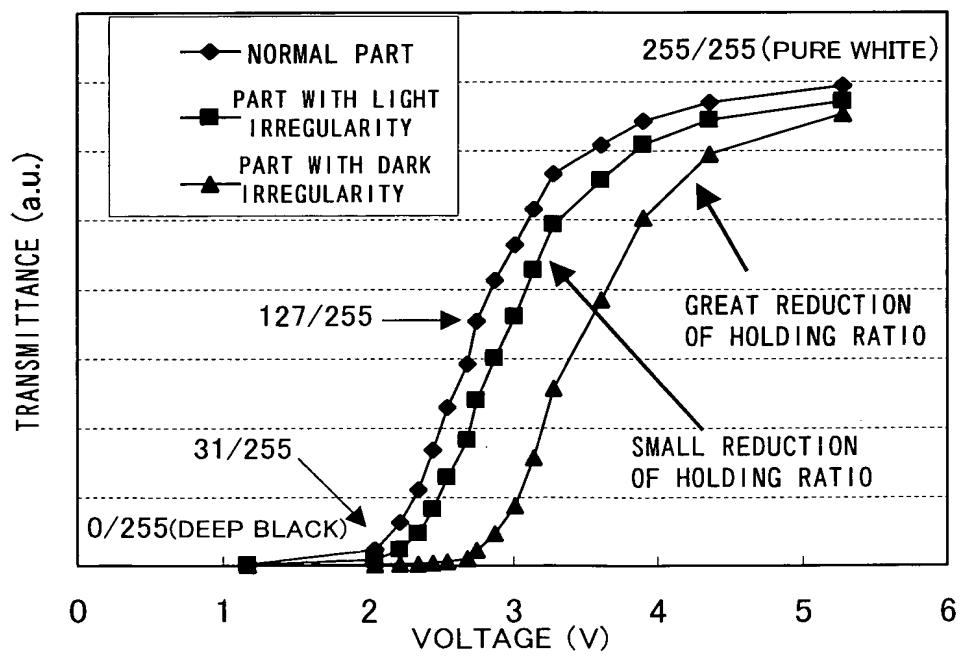


FIG.20



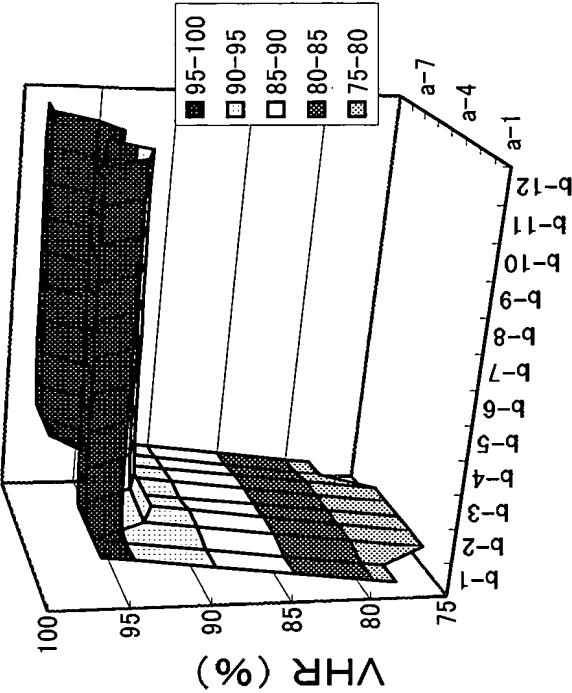


FIG.21(b)

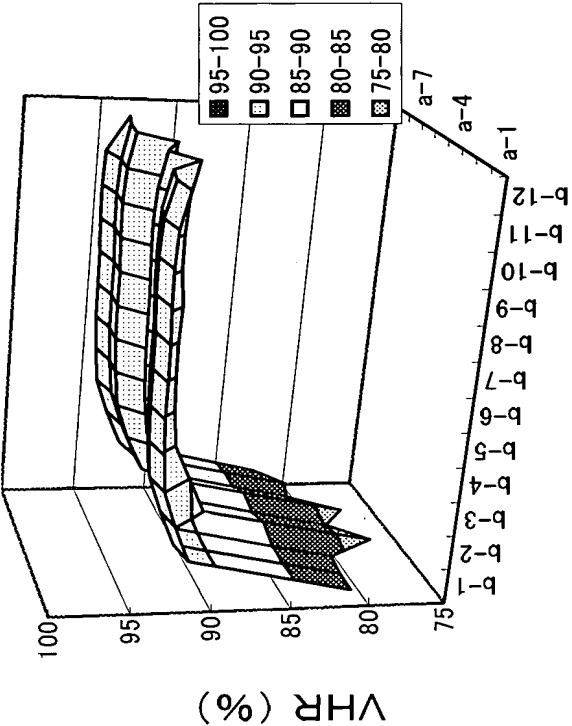


FIG.21(a)

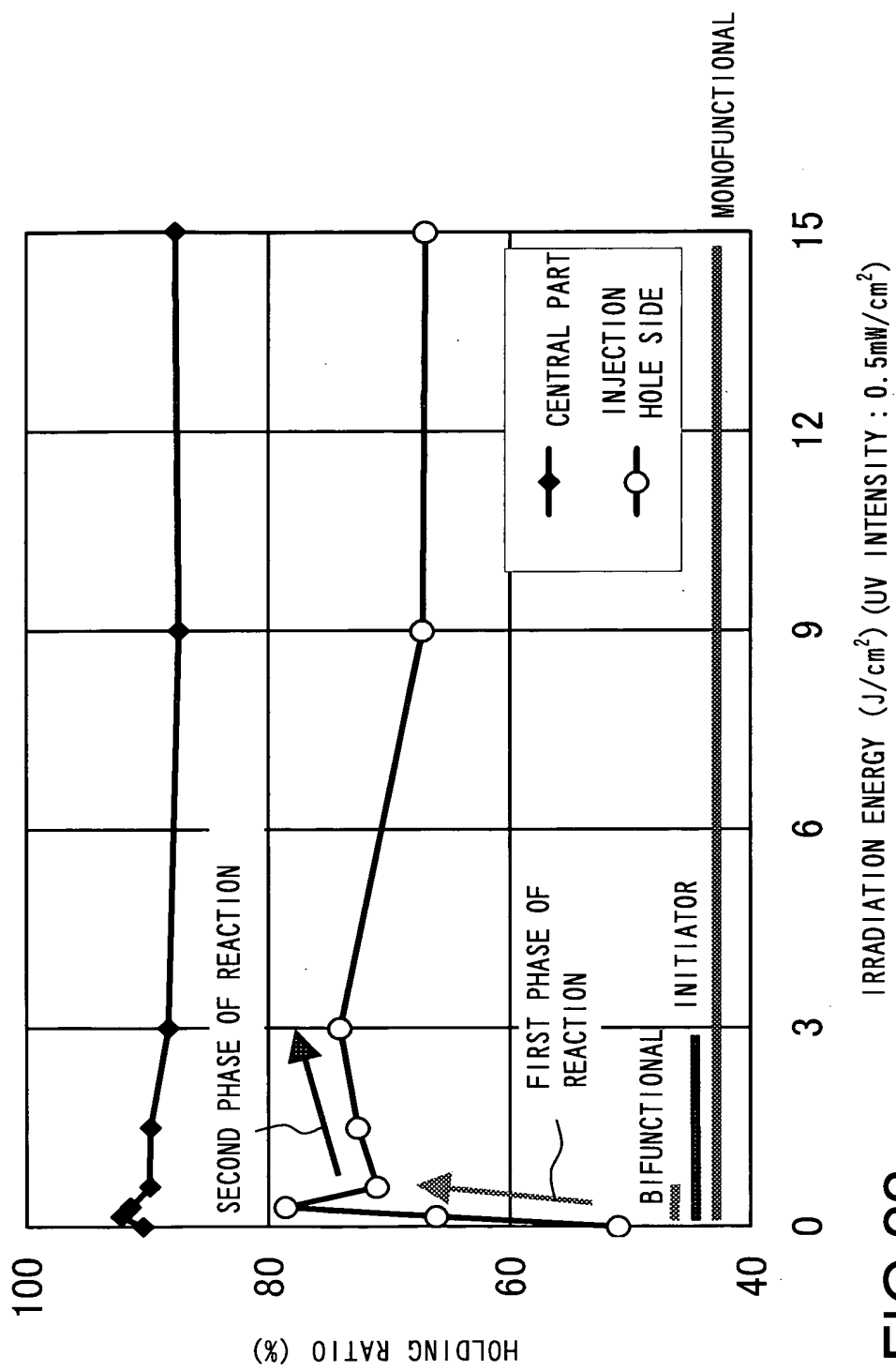
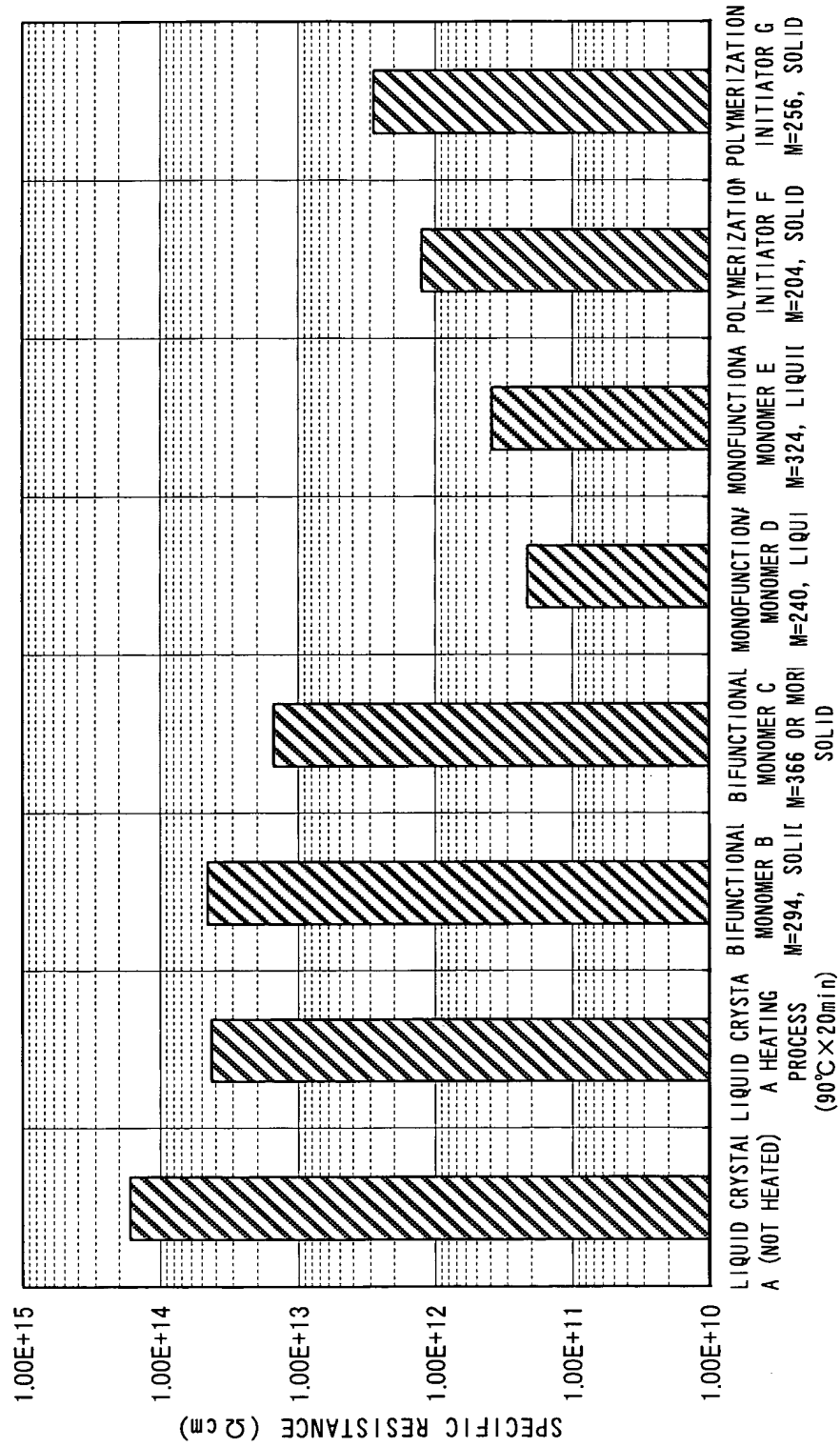


FIG.22

FIG.23
COMPARISON OF SPECIFIC RESISTANCE (LIQUID CRYSTAL A + ACRYLATE)



SAMPLE CONDITIONS

FIG.24

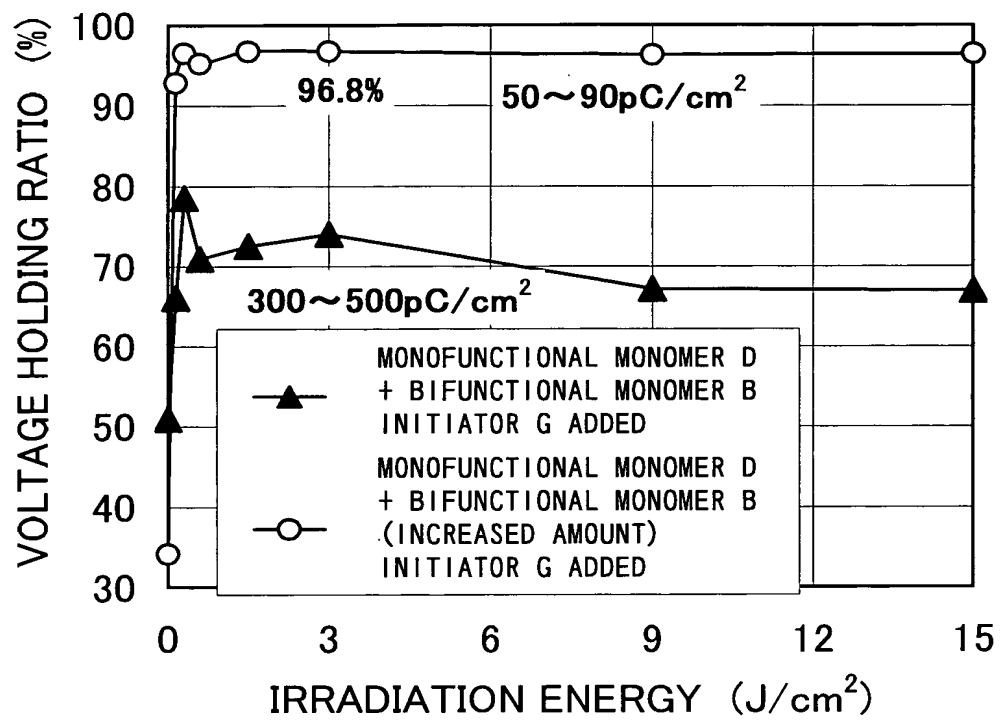


FIG.25

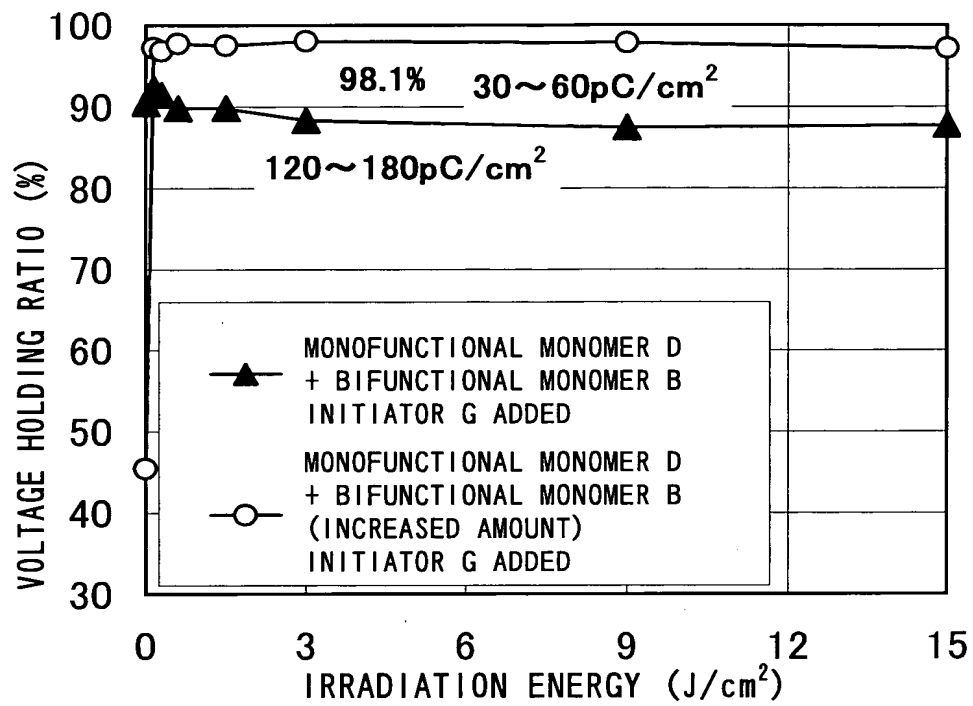


FIG.26

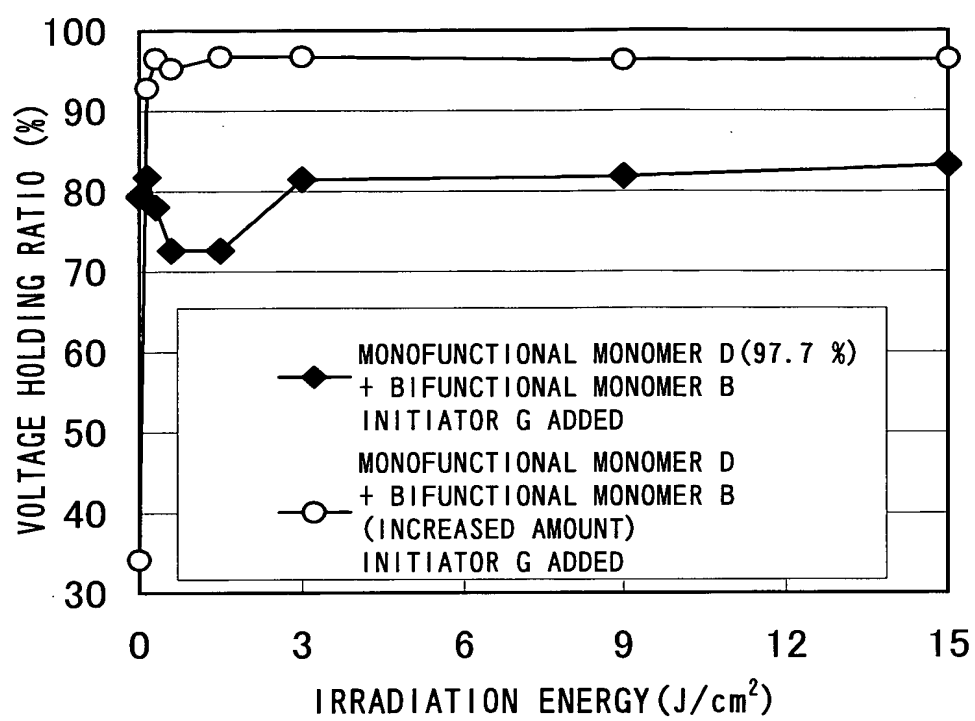


FIG.27

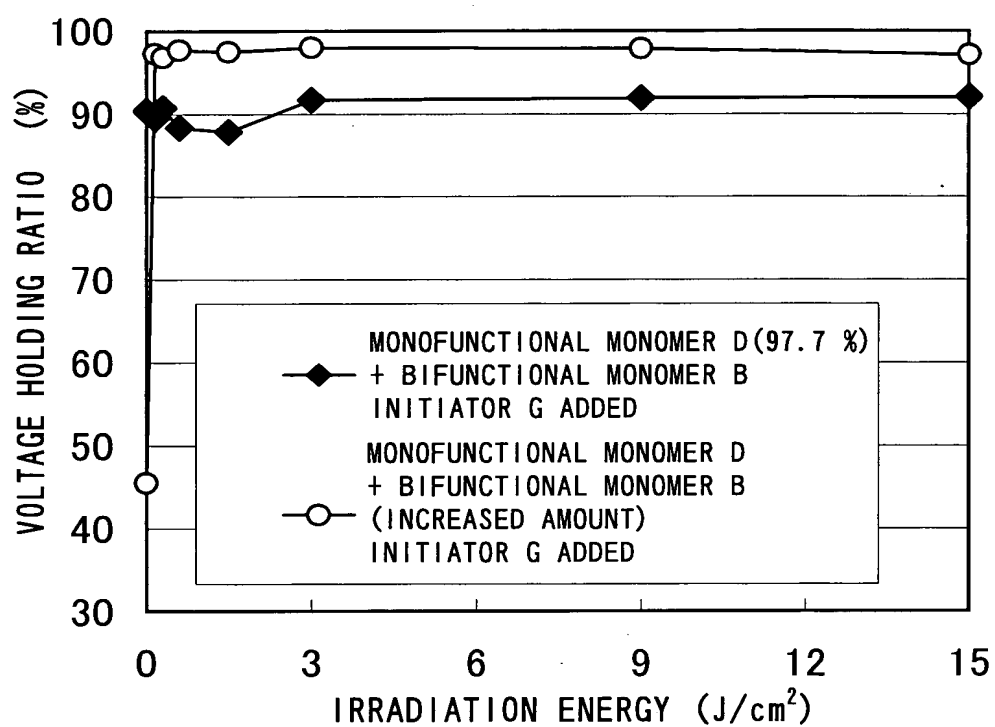


FIG.28

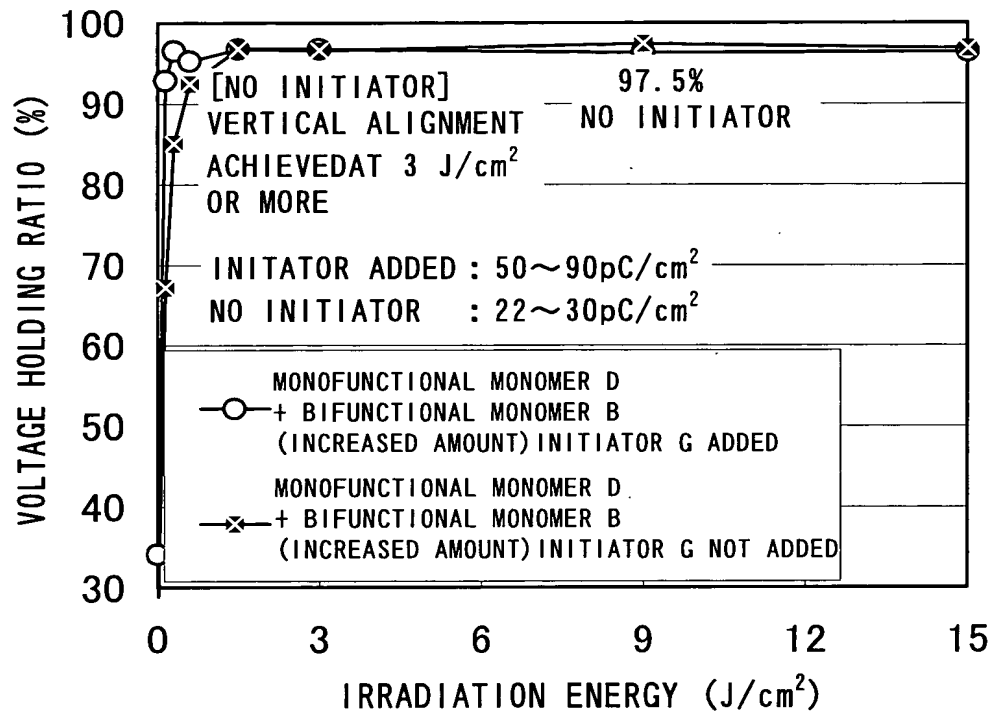


FIG.29

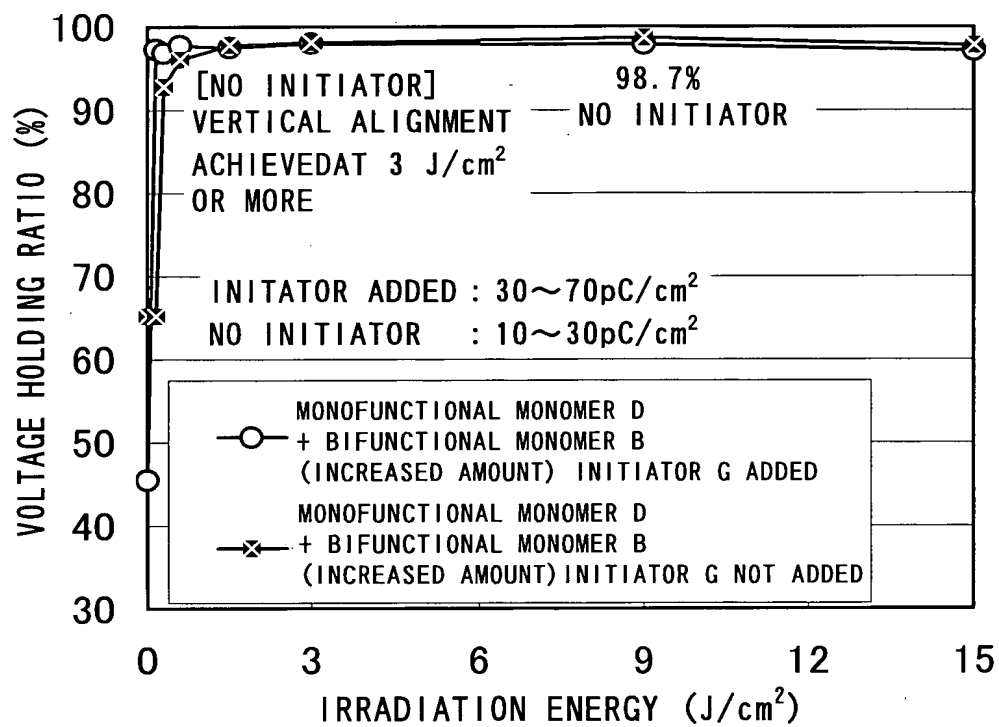


FIG.30

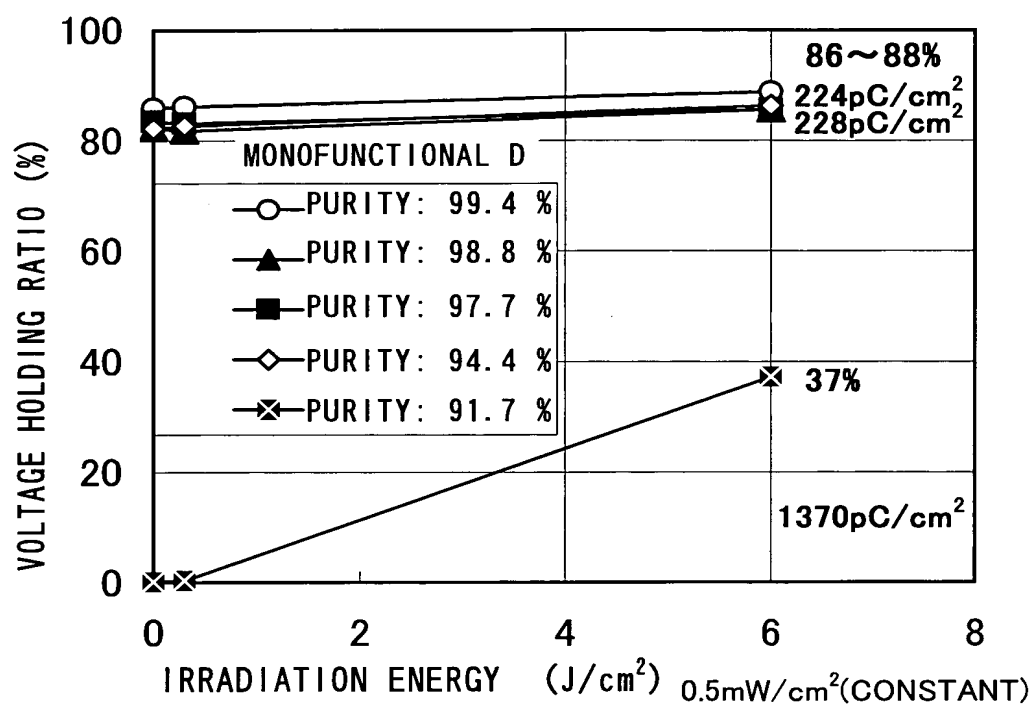


FIG.31

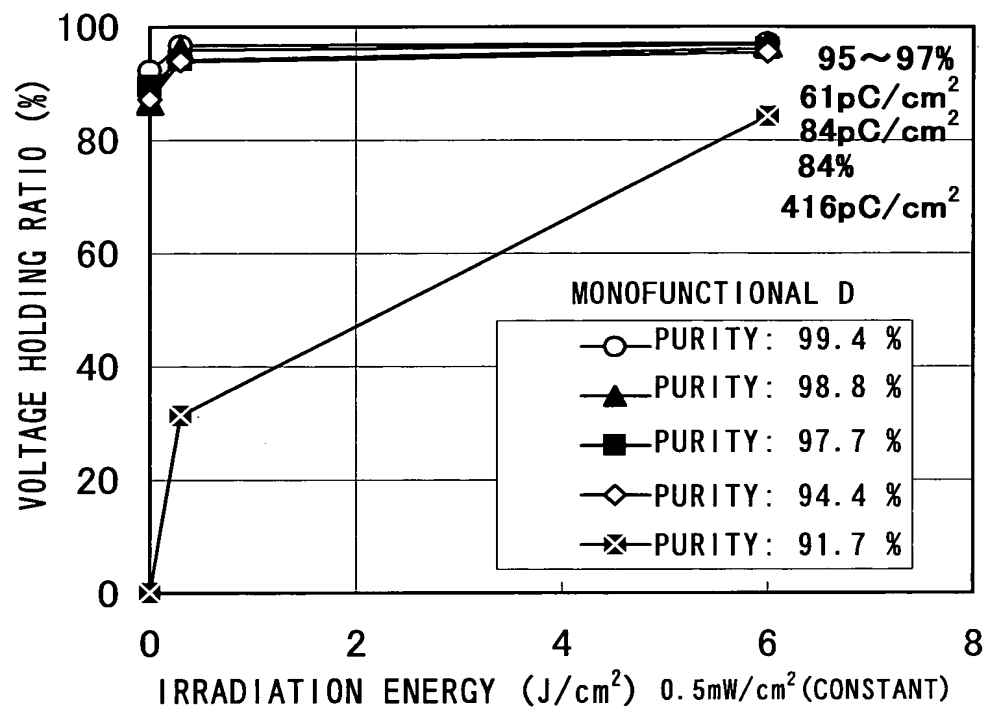


FIG.32

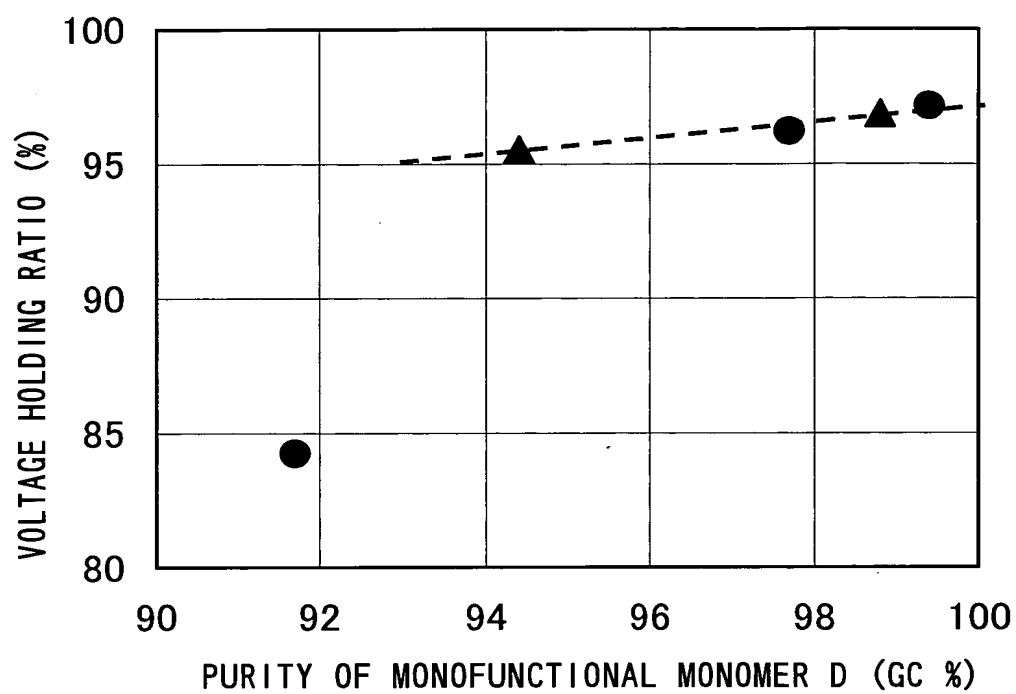


FIG.33

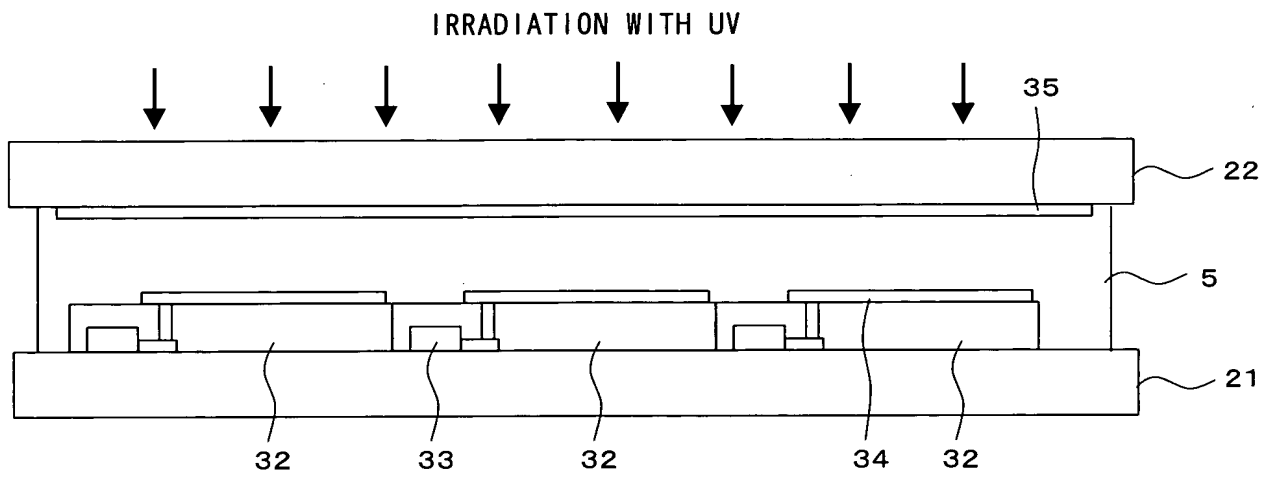


FIG.34

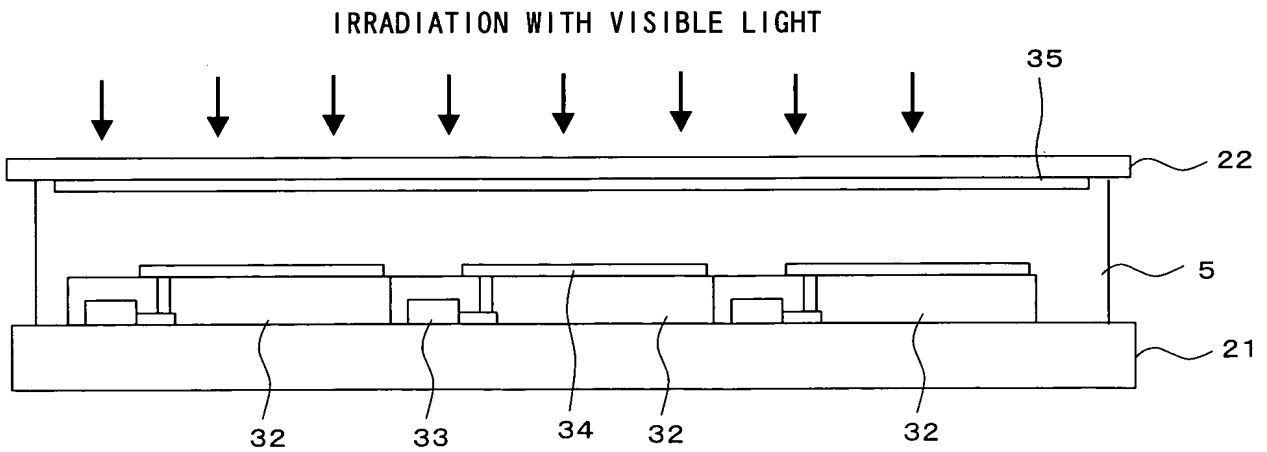


FIG.35(a)

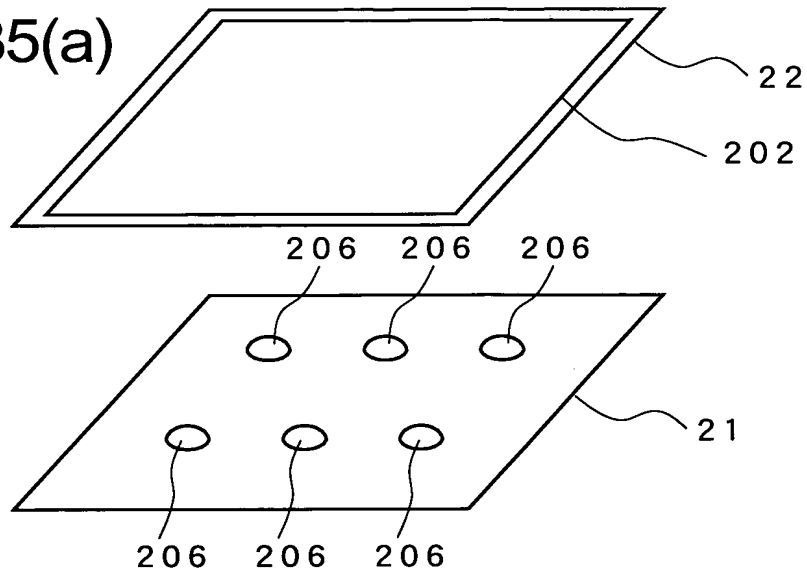


FIG.35(b)

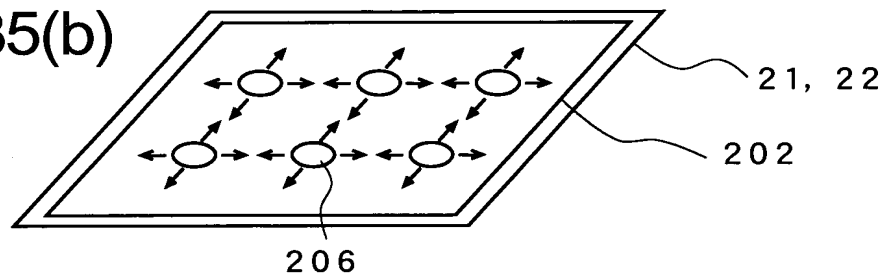


FIG.35(c)

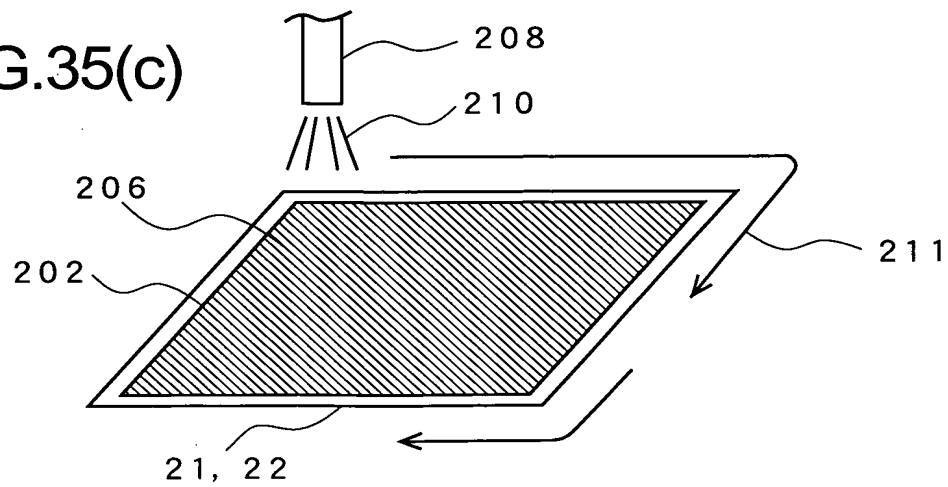


FIG.36(a)

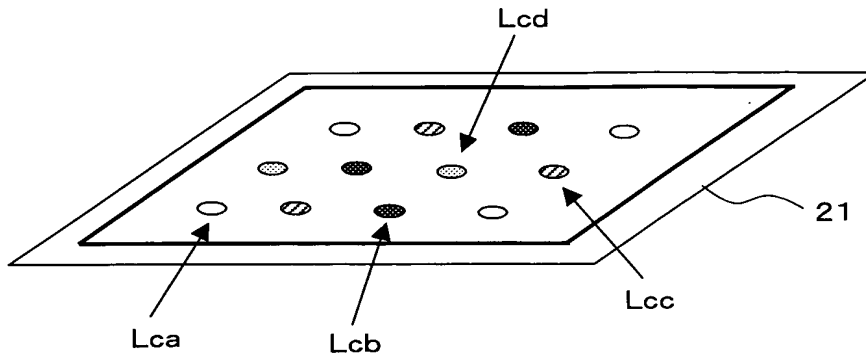


FIG.36(b)

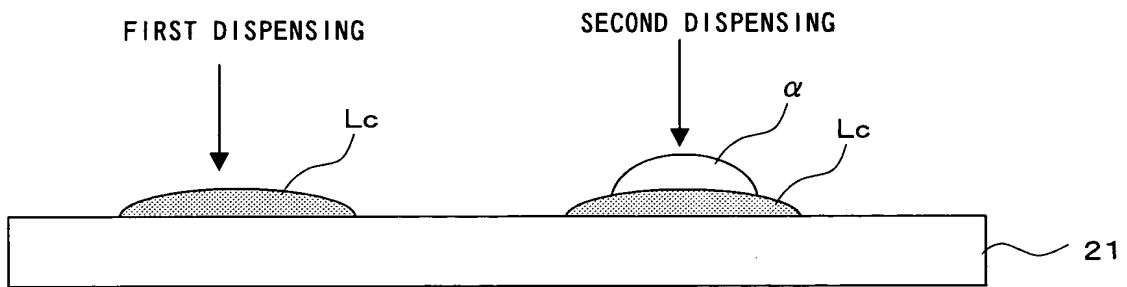
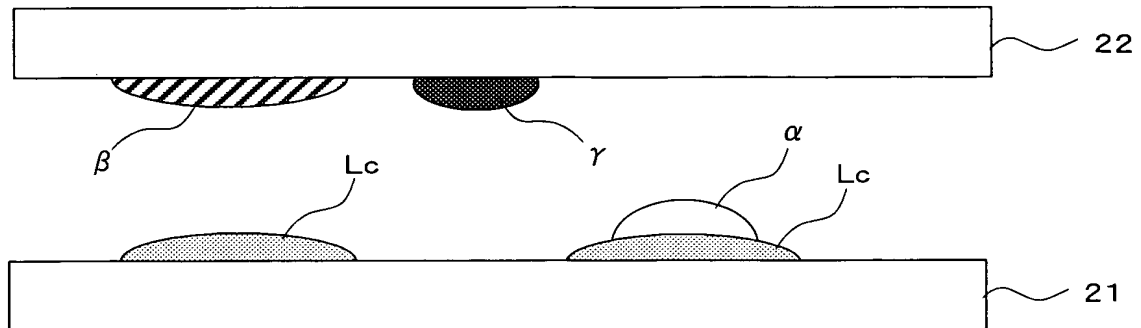


FIG.36(c)



[Name of Document] ABSTRACT

[Summary]

[Problem]

The invention relates to a liquid crystal display utilizing a vertically aligned state of liquid crystal molecules when no voltage is applied and to a method of manufacturing the same. The invention is aimed at providing a liquid crystal display and a method of manufacturing the same in which the existing step for forming vertical alignment films can be omitted to achieve a cost reduction.

[Solving Means]

The liquid crystal display includes a monofunctional monomer having a structure expressed by chemical formula 1:

[Chemical formula 1]

X-R

(where X represents an acrylate group or a methacrylate group, and R represents an organic group having a steroid skeleton). A liquid crystal material is sandwiched between substrates which is then irradiated with ultraviolet rays to cure the monofunctional monomer, thereby forming a polymer film at an interface of a substrate. The monofunctional monomer has a hydrophobic skeleton such as an alkyl chain and a photoreactive group on one side of the skeleton.

[Selected Figure]

Fig. 1